State of California
The Resources Agency
Department of Water Resources

SP-E4: FLOOD MANAGEMENT STUDY

FINAL REPORT

Oroville Facilities Relicensing
FERC Project No. 2100

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State of California	The Resources Agency	Department of Water Resources

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REPORT SUMMARY

The following is a brief summary of reports that were reviewed or information that was gathered as part of Study Plan E4.

Feather River Floodplain and Water Surface Profiles

This report presents, for the Feather River from Oroville Dam to the mouth of the Yuba River, maps of floodplains for the floods with 1% and 0.2% probability of exceedence, floodway boundaries for the flood with 1% probability of exceedence, and water surface profiles for the floods with 10%, 2%, 1%, and 0.2% probability of exceedence. It also describes the study reach, the parameters of the study that developed the information, and the sources of input data.

The draft floodplain maps, completed by the U.S. Army Corps of Engineers (USACE) in January 2002, show the 1% event contained within the levee system. New concerns about levee certification are requiring reassessment for the entire study area in fiscal year 2005-06 when State funding is expected be available for this effort.

A downstream study, from the mouth of the Yuba to the mouth of the Feather at the Sacramento River, is being finalized at USACE. Completion of this draft is expected by December 2004. That study considers the new levee concerns and will not require reassessment. The downstream study will indicate that some floodplain boundaries generated in the upstream study will require revision.

Both studies were performed to Federal Emergency Management Agency (FEMA) standards. The results are intended to be used for federal flood insurance purposes.

Forecast Based Operations of Oroville Dam

The objective of this report is to describe the history, present status, and prospective future implementation of forecast-based operations (FBO) and forecast-coordinated operations (FCO) on two tributary systems of the Sacramento River: the American River and the Feather and Yuba Rivers. The report is needed to assess the practicality at Lake Oroville of flood operations based on weather forecasts.

The use of FBO and FCO on the Feather-Yuba system is directly related to the operation of Lake Oroville, the principal flood control reservoir on the Feather River, and the operation of New Bullards Bar Reservoir, which provides flood control on the North Yuba River. The information on the use of FBO on the American River serves as an example of its application to a nearby and in some ways similar stream and helps assess the state of the art.

The report concludes that the use of FCO on the Feather-Yuba system has the potential to substantially improve flood protection, and summarizes steps to be taken to implement FCO. The report also concludes that the benefits of FBO are less certain yet it identifies the benefit of opening dialog with USACE.

Yuba-Feather Supplemental Flood Control Program

There is a long history of flood damage from waters of the Yuba and Feather Rivers, including multiple levee failures in Yuba County and across the Feather River in Sutter County. There is a similarly long history of efforts to reduce the damages, including levee building since the late nineteenth century and construction of water projects including reservoirs with flood control reservations. Recent flood control works have been developed by USACE, The Reclamation Board of the State of California, and local agencies such as the Yuba County Water Agency (YCWA), working together. In the 1990s, YCWA concluded that additional efforts were necessary and began the Yuba-Feather Supplementary Flood Control Project (YFSFCP) in 1997 with a goal "to define and implement as soon as possible a cost-effective, practicable program of measures to achieve a reliable level of protection against floods from the Feather and Yuba Rivers (YCWA 1998)." YCWA considers the criterion determining a reliable level of protection to be, for a flood event having a 0.2% probability of occurrence, a reduction of 330 thousand acre-feet (taf) in volume passing Shanghai Bend, south of Marysville, when the flow rate exceeds 300,000 cubic feet per second (cfs). Before 1997, this was equivalent to attenuating the 500-year flood peak to 300,000 cfs. The YFSFCP was undertaken in the wake of a major flood in January 1997 that resulted in failure of the Feather River levee in Yuba County below the Yuba River confluence.

YCWA had assembled an advisory group of consultants, defined a study program, developed a process to screen proposed flood control measures, and begun to formulate and analyze alternatives when three significant changes occurred in the project environment following the January 1997 flood. First, the Legislature enacted SB 496, which made the South Yuba River a Wild and Scenic River, eliminating new reservoirs on the river. Second, the Legislature enacted AB 1584, which established Yuba Feather Flood Protection Program (YFFPP) grants for flood protection projects on the Yuba and Feather Rivers. Third, USACE re-evaluated the hydrology of the area, so that the event formerly designated the 500-year flood at Shanghai Bend now is estimated to recur on an average of approximately 200 years. YCWA restated their goal in terms of the YFFPP in response to the new conditions, retaining the 330-taf reduction but applying it to a larger flood now estimated to have a 500-year average recurrence period (YCWA 2001; YCWA 2002b).

Now proceeding under a YFFPP feasibility study grant, YCWA has examined 37 measures, retaining five for probable implementation under the YFFPP. The surviving measures are storage increase at New Bullards Bar Reservoir, enlargement of outlets at New Bullards Bar Reservoir, tailwater depression at New Colgate Power Plant, FBO at New Bullards Bar Reservoir and Lake Oroville, and levee setback on the Feather River. Because these measures collectively fall short of meeting the stated goal, YCWA is also leaving the way open for additional projects in the future (YCWA 2001; YCWA 2002b).

The feasibility study under the YFFPP is nearly completed and a second YFFPP grant for design is anticipated, followed by cooperative construction financing with YFFPP and other funds (pers. comm., Yamanaka, 2003).

Sacramento and San Joaquin River Basin, Comprehensive Study

The objective of the Sacramento and San Joaquin River Basins Comprehensive Study is to develop a paradigm for projects on those rivers and their major tributaries that will solve flooding and ecosystem problems more effectively than present methods do. The Comprehensive Study has developed such a paradigm involving guiding principles, an approach to project development, and an administrative structure. The Study also has reported general findings about the flood control systems on the Sacramento and San Joaquin Rivers and their past and continuing effects on the environment.

The Interim Report of the Comprehensive Study describes the setting, the methods used by the Study, the Study's findings both overall and region-by-region in seven regions, and the technical models that the Study assembled as part of the project development approach. The guiding principles are enumerated and these important overall findings stated:

- There are locations where the flood control system cannot carry design flows.
- To avoid downstream impacts, upstream storage increases must accompany levee improvements.
- A comprehensive solution to flooding problems will include better levees, more storage, and better floodplain management (USACE 2002b).

The Comprehensive Study's approach to project development is now being demonstrated in the Hamilton City project. USACE has prepared a draft feasibility study/environmental impact statement (EIS)/environmental impact report (EIR) under Comprehensive Study principles. The study identified a cost-effective, technically feasible, and locally acceptable project to reduce flood damages and restore the ecosystem. The tentatively recommended plan includes 6.8 miles of setback levee and training dike and 1480 acres of ecosystem restoration with a cost of about $45 million and a flood damage reduction benefit/cost ratio of 1.8. The Reclamation Board certified the EIS/EIR, adopted findings, and approved the recommended plan in July 2004. The draft document is under federal review. Past attempts to deal with chronic flooding in Hamilton City and vicinity had focused only on the flood control aspects, for which it had not been possible to develop a cost-effective project (USACE 2003b).

The system-wide Enhanced Flood Response and Emergency Preparedness (EFREP) project is also a Comprehensive Study project. USACE prepared a preliminary draft feasibility study/Environmental Assessment/Initial Study in September 2003 that describes three alternatives developed for EFREP in response to a recommendation of FEAT in 1997. The draft report tentatively recommends the “moderate” plan, which includes all of the features of the ”minimum” plan plus additional flood detection features. It includes enhancement of flood detection, flood notification, and decision making. It would increase the flood warning time (mitigation time) an estimated 0-31 hours (USACE 2003c), reducing the estimated annual flood damages by 6.5 percent, or about $6 million annually. Non-federal interests would be responsible for about $2.4 million annual costs (USACE 2003c). After deducting annual costs, net annual benefits would be $3.7 million. The draft report shows an estimated initial cost of $10.3 million to be shared 65% federal, 35% non-federal.

Sutter County Feasibility Study

The object of this report is to present the purpose and status of the Sutter County Feasibility Study (SCFS). USACE, The Reclamation Board, and Sutter County are conducting the SCFS to investigate alternatives to reduce future flood damages on the Sacramento River, the Feather River, the Sutter Bypass, and other watercourses in Sutter County. The study focuses on the integrity of the facilities of the Sacramento River Flood Control Project, particularly at those locations where flooding problems have been most likely to occur. The SCFS will also investigate opportunities to integrate ecosystem restoration measures and will produce an environmental document (TRB 2003).

The SCFS is in progress. The schedule calls for release of a feasibility study report for public review in 2006. The study has gathered extensive geotechnical and topographic information, adapted models of the Comprehensive Study for SCFS use, and made a preliminary assessment of potentially viable alternatives. USACE produced for internal use a preliminary draft feasibility scoping milestone report in May 2004 that presented the without-project condition of the study area. The draft also identified 11 flood damage reduction measures and five potential sites for ecosystem restoration measures (USACE 2004b). Economic analysis has not been completed, but according to USACE staff, measures involving levees outside the Yuba City area appear unlikely to prove beneficial (pers. comm., Baker, 2004a). The results of the SCFS are expected to be a final feasibility study report and an EIS/EIR. If economically feasible alternatives are identified, a project could be in place by 2010 or later depending on project complexity, federal, State, and local financing, and other factors. (pers. comm., Baker, 2004b)

Levees: Inspection, Maintenance, and Adequacy

The Floodplain Study by USACE (Section 5.0) had demonstrated that the levee system adequately satisfies FEMA criteria as well as USACE concerns. The maintenance reports for the Feather River levees indicate that generally the level of compliance with the USACE Manual is “Good” to “Outstanding”.

As always, floodplain analyses and levee assessments are subject to change. The best and most current information has been used; however, as new data is provided, it will be included. USACE had formed a Levee Stability Task Force to examine levee seepage issues as they may relate to overall levee stability. Current USACE levee certification criteria requires reassessment of this study in 2005 pending available funding.

Emergency Action Plan for Oroville Facilities

The last complete reprint was submitted to the Federal Energy Regulation Commission (FERC) on March 10, 2000 and FERC by its letter dated April 4, 2000 acknowledged that the reformatted Emergency Action Plan (EAP) had been prepared in accordance with the revised Chapter 6 of the FERC Engineering Guidelines. The DAMBREAK analysis was also conducted and the revised inundation maps were updated in October 2000 and submitted to FERC on November 29, 2000.

Probable Maximum Flood for Lake Oroville

Preliminary results (pending regulatory approval), indicate that the 2003 probable maximum flood (PMF) peak inflow is less than the 1980 estimates by USACE. The difference in the 1980 and 2003 PMF is due to the change in precipitation based on HMR 36 and HMR 59 respectively. The 2003 HEC-HMS model is recommended as an updated, calibrated model and the resulting PMF is recommended for use in subsequent operational studies for Lake Oroville. The PMF routing considering full operation of all spillway gates and the effect of non-operation of one and two spillway gates is under way at this time.

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1.0 INTRODUCTION

Flood management is one benefit that was delivered by Oroville Dam even before it was complete. While the dam was under construction, it prevented millions of dollars of property damage and saved lives by impounding the floodwaters in 1964. Today, flood management remains one of the major benefits of this dam.

Flood management is essential for the health, safety, and economy of the area exposed to such hazards. Even after the construction of Oroville facilities, areas along Yuba River and Feather River (downstream of Oroville dam) have experienced major floods several times such as in 1986 and in 1997.

Since the construction of Oroville Facilities in 1967:

1. Natural growth over time has increased both the extent and the intensity of development in the Feather River and Yuba River flood plains.
2. Changes in the regulatory and environmental laws have taken place.
3. Significant advances have been made in:

    - The collection/application of real-time data for forecasting reservoir inflow
    - The science of hydrology, topographic, and geographic mapping
    - Computer software used in hydrologic and flood routing studies
    - The engineering of flood control structures

Additional water storage facilities have been planned or constructed in the Sacramento and San Joaquin River basins.

Consequently, since the construction of Oroville Facilities, older studies have been updated and new studies have been completed. In addition, studies by various agencies are currently underway to find ways to improve flood management for the Sacramento River and its tributaries, including the Feather and Yuba Rivers

Flood Management is a highly complex subject involving various dam owners/operators, local governments, state and federal resource agencies, regulatory bodies, and the people affected by the floods. Floods are basin-wide and regional problems and require regional, coordinated solutions among various agencies.

This report is a compilation and summary of known flood control studies involving the Feather River. It contains 15 sections, various embedded tables and figures, and two appendices. The glossary is not included but available on the Department of Water Resources (DWR) web site at http://orovillerelicensing.water.ca.gov/pdf_docs/glossary.pdf (DWR 2003) or by requesting a copy of the current version.

1.1 BACKGROUND INFORMATION

1.1.1 Statutory/Regulatory Requirements

1.1.1.1 Federal Energy Regulatory Commission

The Federal Power Act provides the Federal Energy Regulatory Commission (FERC) with jurisdiction over flood control as part of its licensing authority. However, Congress specifically vested the Secretary of the Army with flood control operations at the Oroville Facilities. FERC acknowledged this when it amended the license and added Article 50, clearly stating that flood control operations would be pursuant to the rules and regulations of the Secretary of the Army. Below are the two license articles relating to flood control operations at Oroville Facilities:

Article 50. The operation of the project in the interest of flood control as provided in Article 32 of the license shall be in accordance with the rules and regulations to be prescribed by the Secretary of the Army pursuant to Section 204 of the Flood Control Act of 1958. (Order amending license-major, Issued January 22, 1964)

Article 32. The licensee shall collaborate with the Department of the Army in formulating a program of operation for the project in the interest of flood control. (Order issuing license-major, December 14, 1956)

1.1.1.2 United States Army Corps of Engineers

Flood management operations at the Oroville Facilities are in accordance with flood control regulations prescribed by the Secretary of the Army and administered by the U.S. Army Corps of Engineers (USACE). The primary objectives of flood control operation are to:

- Minimize flood damages downstream; and,
- Avoid causing damage that would not have occurred under conditions without the facilities.

The primary design considerations and resulting regulations are listed below:

The Standard Project Flood at Oroville

The standard project flood (SPF) has a peak flow of 440,000 cubic feet per second (cfs) and a 3-day run-off volume of 1,520 thousand acre-feet (taf) and is estimated to inundate close to 292,000 acres. This SPF results from the standard project rainstorm of 96-hour duration depositing 14.3 inches of precipitation on wet ground in the drainage basin above the dam.

The Probable Maximum Flood for Oroville Dam

The probable maximum flood (PMF) is based on the probable maximum precipitation (PMP), considering both rain and snow, and is used for spillway design purposes. USACE estimated the PMF in 1970 to have a peak flow of 720,000 cfs and a 3-day runoff volume of 2,510 taf and results from a 72-hour storm depositing 21.1 inches of precipitation.

The PMF study was updated by USACE in 1980. It showed that the PMF has a peak inflow of 960,000 cfs and an 8-day run-off volume of 5,217 taf.

Flood Control Space Requirement

Flood control space requirements for Oroville Reservoir was based primarily on protection of urban and agricultural areas along the Feather River below the reservoir against winter floods up to a magnitude of the SPF. Flood control space requirements, determined through planning studies, vary from a minimum of 375 taf to a maximum of 750 taf.

Release Requirement

Maximum flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with USACE. Minimum release requirements were mutually agreed between the State of California and the United States. In order to fully utilize downstream channel capacities and flood control space under various flood conditions, a release capability of 150,000 cfs was determined desirable, the State and the United States agreed that a smaller release at lower reservoir levels would be acceptable. A release capacity of 75,000 cfs with the reservoir level at the bottom of the flood control storage space and 150,000 cfs release capacity with the reservoir water surface elevation at 863.5 feet above meal sea level (msl) were agreed to. Subsequent studies indicated that the release capacity of the flood control outlet with the reservoir water surface elevation at 848.5 feet above msl (bottom of the flood control storage space) was 85,000 cfs. This value was used for reservoir regulation purposes.

1.1.1.3 The Reclamation Board

The Reclamation Board was created by the California Legislature in 1911 to carry out a comprehensive flood control plan for the Sacramento River, the San Joaquin River, and their tributaries. The Reclamation Board cooperates with USACE in controlling flooding along the Sacramento and San Joaquin Rivers and tributaries. For nearly 90 years, the Board has acted as liaison between the State of California and the United States, residents, property owners, and agencies in the Central Valley.

Under California law, no reclamation project of any kind may be started or carried out on or near the Sacramento and San Joaquin Rivers or their tributaries until plans have first been approved by the Board. The Board's efforts focus on controlling floodwater; reducing flood damage; protecting land from floodwater erosion that would affect flood control project levees; and controlling encroachment into floodplains and onto flood control works, such as levees, channels, and pumping plants.

The Board uses both structural and nonstructural measures to accomplish its purposes. It assists USACE, the federal agency that funds and builds flood control projects, by providing lands, easements, rights of way, and relocations. When a project is completed, the Board accepts responsibility for the project and usually turns it over to a local agency to operate and maintain. The Board also plans and adopts designated floodways, which are nonstructural means of ensuring the safe passage of flood flows through flood-prone areas. The Board has adopted more than 1,300 miles of designated floodways in the Central Valley.

1.1.1.4 Local Agencies/Reclamation Districts

Local agencies/reclamation districts are responsible for the operations and maintenance of the flood control levees in their custody. These levees must be maintained in accordance with the maintenance instruction prepared by USACE and adopted by The Reclamation Board.

1.1.2 Study Area

1.1.2.1 Description

For purposes of this study we have defined the study area as the FERC Project 2100 Boundary, the Feather River watershed upstream of Oroville Dam, and the Feather River downstream to the confluence with the Yuba River. However, the study areas for the flood control studies summarized in the text of this report vary greatly. Individual descriptions are included as part of the respective discussions in the report.

1.1.2.2 History

Beginning with local levee construction soon after the 1849 California Gold Rush, many projects have sought to protect the area from floods.

- Daguerre Point Dam, completed in 1906 as part of the federal Yuba River Debris Control Project, no longer has sediment storage capacity.
- The federal Sacramento River Flood Control Project (SRFCP), authorized in 1917, incorporated preexisting local levees in the present federal levees on the Yuba and Feather Rivers.

- Englebright Reservoir on the Yuba River, completed in 1941 as part of the federal Sacramento River Debris Control Project, has limited capability to provide flood storage.
- In 1959, voters approved a bond issue to construct the Yuba River Development Project and the State Legislature created the Yuba County Water Agency (YCWA).
- The ongoing federal Sacramento River Bank Protection Project, begun in 1965, provides measures to protect SRFCP levees from erosion, using rock riprap and other methods.
- Lake Oroville of the State Water Project (SWP), completed in 1967, provides up to 750 taf of dedicated flood control storage on the Feather River.
- New Bullards Bar Reservoir of YCWA, completed in 1970, provides up to 170 taf of dedicated flood control storage on the North Yuba River.
- The federal Sacramento River Flood Control System Evaluation, Phase II, identified about 25 miles of levees that required reconstruction to restore the design level of flood protection. The resulting Marysville-Yuba City Levee Reconstruction Project is nearing completion and includes slurry walls, berms, restoration of levee height, and drainage facilities (pers. comm., Lerner, 2003).
- In 1999, USACE completed realignment of the west bank Feather River levee at Shanghai Bend under the special Public Law 84-99 Cost-Shared Levee Rehabilitation Program, eliminating a perennial flood threat.
- Repairs of levees damaged in the 1997 and 1998 floods were completed in 1999 under the regular federal Public Law 84-99 Rehabilitation Program.
- In 1999, USACE completed the Yuba River Basin Feasibility Study, requested by YCWA. Work recommended by the Study is in the late stages of design and involves constructing slurry walls, deepening toe drains, and constructing berms. Additional work to deepen slurry walls was done in advance at the same time as the Marysville-Yuba City Levee Reconstruction Project (pers. comm., Lerner, 2003).
- The Sutter County Feasibility Study (SCFS) began in 2000 and includes consideration of levee reinforcement, enlargement and setbacks, and vegetation management on the Feather and Bear Rivers (pers. comm., McQuirk, 2003; YCWA 1998).
- In March 2000, voters authorized the Yuba Feather Flood Protection Program (YFFPP), a part of the Safe Drinking Water, Clean Water, Watershed Protection, and Flood Protection Act, also known as the Costa-Machado Water Act of 2000. The Act authorized $70 million to be used by DWR or The Reclamation Board for grants to a local agency to fund flood protection projects in the Yuba-Feather and Colusa Basin Drain area. $20 million was allocated to the Department of Fish and Game (DFG) to mitigate the impacts of the projects on the environment.

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the SWP, a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3,500 taf capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cfs of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. DFG's habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly, and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion, and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000 taf; however, this does not limit drawdown of the reservoir below that level. If the weather were drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan

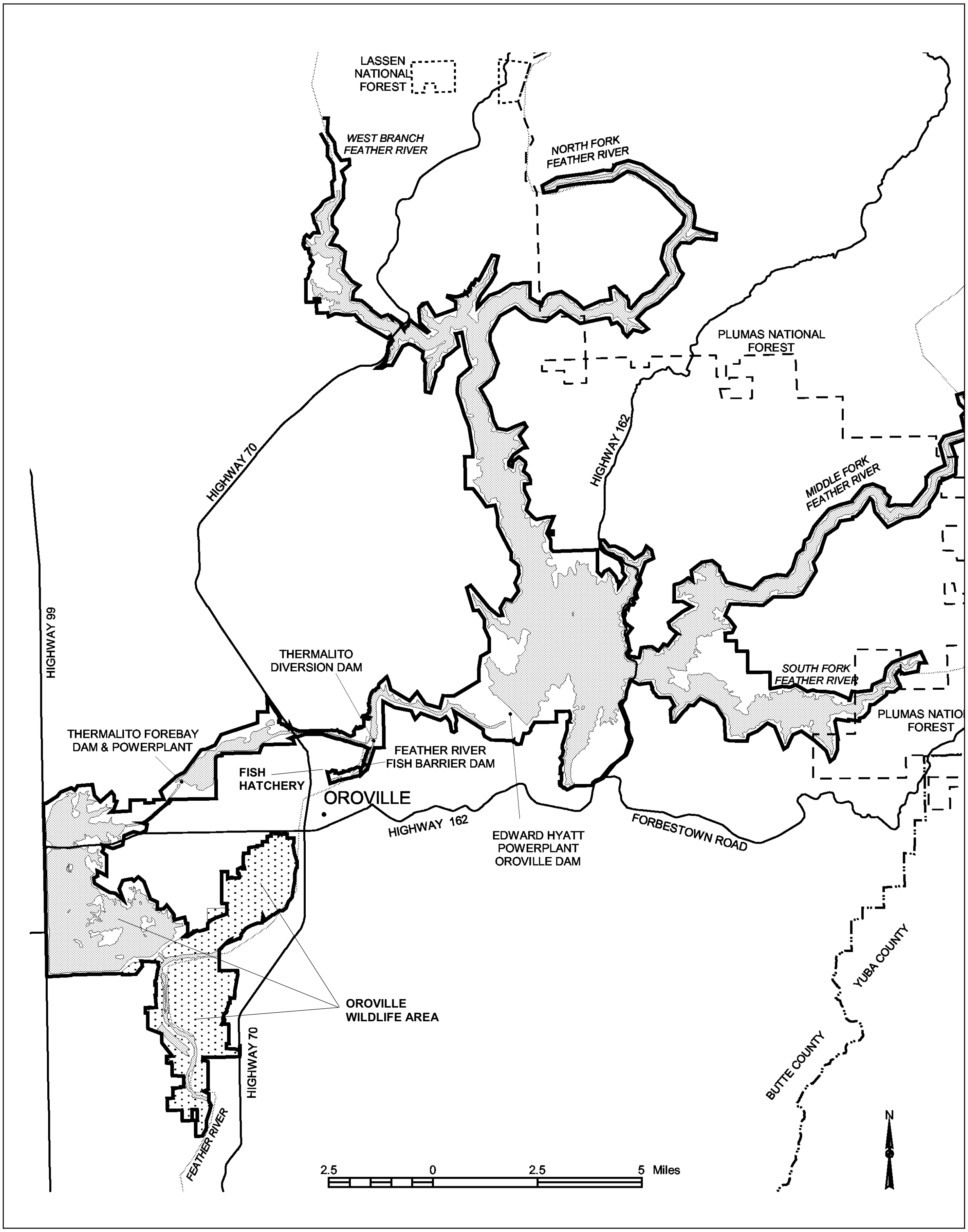


Figure 1.2-1. Oroville Facilities FERC Project Boundary

is updated regularly to reflect changes in hydrology and downstream operations.

Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above msl in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife," sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942 taf (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for

December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California Integrated Systems Operator anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190 taf (occurred July 2002) are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1,000 taf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by USACE. Under these requirements, Lake Oroville is operated to maintain up to 750 taf of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2,800 to 3,200 taf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection.

The actual flood control space required is determined by using the Flood Control Diagram and the ground wetness index. The adopted ground wetness index incorporates a daily reduction in the weight given previously occurring precipitation and is computed each day by multiplying the preceding day's index by 0.97 and adding the current day's precipitation in inches, i.e.;

$$\text{Par} = \text{Par}' \times 0.97 + \text{Precip}$$

Par = ground wetness index for the present day's operation
Par' = previous day's index
Precip = precipitation occurring since Par' was computed.

A wetness index of 11.0 (wet ground conditions) was selected for provision of the full 750 taf of flood control space. A value of 3.5 was selected to represent dry ground conditions and corresponds to the minimum flood control space requirement of 375 taf.

When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

There are two needs for this study in the relicensing process:

1. Document that Oroville Facilities operations follow Federal and State Agencies regulations:

   A comprehensive plan for developing the waterway for the beneficial public use including flood control is required by FERC (18 CFR Subchapter B, Part 4, Paragraph 4.51). The Federal Power Act states that flood control benefits of a project and the recommendations of Federal and State agencies exercising administration over flood control would be considered by FERC:

   "All licenses issued under this subchapter shall be on the following conditions:

   - "Modification of plans; factors considered to secure adaptability of project; recommendations for proposed terms and conditions

     - "That the project adopted, including the maps, plans, and specifications, shall be such as in the judgment of the Commission will be best adapted to a comprehensive plan for improving or developing a waterway or waterways for the use or benefit of interstate or foreign commerce, for the improvement and utilization of water-power development, for the adequate protection, mitigation, and enhancement of fish and wildlife (including related spawning grounds and habitat), and for other beneficial public uses, including irrigation, flood control, water supply, and recreational and other purposes referred to in section 797(e) of this title. If necessary in order to secure such plan the Commission shall have authority to require the modification of any project and of the plans and specifications of the project works before approval.

     - "In order to ensure that the project adopted will be best adapted to the comprehensive plan described in paragraph (1), the Commission shall consider each of the following:
       - "….
       - "The recommendations of Federal and State agencies exercising administration over flood control, navigation, irrigation, recreation, cultural, and other relevant resources of the State in which the project is located and the recommendations (including fish and wildlife recommendations) of Indian tribes affected by the project…."

(Title 16-Conservation, Chapter 12-Federal Regulation and Development of Power, Subchapter I-Regulation of the Development of Water Power and Resources, Sec. 803 -Conditions of License Generally)
The information contained in this report outlines the requirements (recommendations) set forth by USACE, the federal agency exercising administration over flood control at the Oroville Facilities.

2. Address issues identified and comments received in the scoping process:

   A number of issues were identified and comments received during the scoping process. These are listed in Table 2.0-1.

   To address these issues, the existing information from various sources was retrieved, compiled, and summarized. New flood management studies would be conducted only if necessitated by any changes proposed in the Relicensing Application.

Table 2.0-1. Stakeholder issues addressed.

EE17 - - update flood operation manual
EE19 - - early warning system for downstream releases
EE56 - - prepare flood inundation maps for a 1997(?) worse case with 300,000 cfs coming out of the dam's normal and emergency spillways. In 1997, it is believed that Oroville storage was almost to a point where the 300,000-cfs of inflow was going to pass through the reservoir. DWR was making plans to evacuate the power plant. The 300,000 would have topped the levees and put 10 feet of water into the town of Oroville.
EE11 - - coordinate releases with other water storage facilities for flood release
EE21 - - outflow impacts to downstream flood risk (levee stability) USACE?
EE22 - - stability of Oroville levee system through low flow section and effects of high flow
EE23 - - evaluate channel capacities and potential need for more storage / flood protection engineering and operations deflection into levees by gravel bars
EE47 - - in the FERC Part 12 guidelines, the PMF is to be examined after each major flood event. The Feather River has had two major flood events since 1971; once in February 1986 and again in January 1997. The FERC Part 12 regulation guidelines also state that when new Hydrometeorological Reports (HMR's) are issued, the PMF is to be re-examined. New HMR's (HMR 58 & 59) were issued in 1999, thus precipitating the Oroville 2100 project to be re-examined in light of the new data. I think that this has been done for the 2100 project in the last Part 12 inspection and the Work Group should be given the correct data. If not done, the question is why not?
EE51 - - provide the Work Group with the study data done on installing Obermeyer Gates on the emergency spillway ogee to raise the reservoir elevation in a major flood runoff event? What is the probability of this installation?
EE52 - - provide the workgroup with the latest PMF, HMR, and PMP data?
EE53 - - when was the last "Inflow Design Flood" study done and was it done on current data?

3.0 STUDY OBJECTIVE

The general objective of this study is to document current flood control requirements, analyze flood management under current operations, and identify opportunities for future improvements in flood management.

4.0 METHODOLOGY

4.1 STUDY DESIGN

The general approach of the study as outlined in the study plan was to:

Evaluate and, if necessary, update existing studies to reflect current conditions, technology, and information, including:
- Estimating the storm precipitation
- Estimating runoff and flood routing
- Inundation studies

Identify and evaluate potential future alternatives regarding flood management, including:
- Measures for advance information for inflow into Oroville reservoir
- Structural modifications in the project facilities
- Changes in the operations of dam

Coordinate with and incorporate the results of relevant studies being done by other agencies as listed in Task 1, 2, and 3 of the study plan.

The more detailed methodology outlined only four tasks that needed to be completed. The results of those four tasks are the basis for this report.

4.2 HOW THE STUDY WAS CONDUCTED

The study plan contained four basic tasks: 1) review existing or in-progress literature on Feather River floods, 2) update studies if the review of the existing and in-progress studies shows that current information would significantly change the conclusions of these studies, 3) coordinate and cooperate with ongoing studies by other agencies, and 4) prepare report summarizing the work completed in each task.

4.2.1 Task 1

Seven existing or in-progress studies or activities to be reviewed under Task 1 were identified in the study plan, listed below:

- Oroville Dam PMF Analysis
- Feather River Backwater Analysis by USACE 2001
- Forecast Based Operation (Advance Release) of Oroville Dam
- Sacramento and San Joaquin River Basins, Comprehensive Study
- Yuba-Feather Supplemental Flood Control Project (YFSFCP)
- Review Emergency Action Plan (EAP) for Oroville Facilities
- Sutter County Feasibility Study.

DWR staff has reviewed these seven studies or activities. Relevant information is presented in this report. Additionally, in the report is information gathered on the levee system which should address selected stakeholder issues.

4.2.2 Task 2

Results of Task 1 indicate that the existing and in-progress studies used state of the art information and no updates were deemed necessary. We have also determined that since FERC defers to USACE on matters of flood control, it would be very unlikely that relicensing activities would result in conditions that would alter the results of existing or in-process studies. However, DWR as part of its ongoing operations continues to participate in relevant in-progress activities and may participate in the efforts to update relevant studies outside of the relicensing process.

4.2.2 Task 3

We held several coordination meetings with DWR and other agency personnel involved with in-progress studies and have determined that DWR will continue to participate in these activities, as it has in the past, outside of the relicensing process.

4.2.3 Task 4

This report summarizes the information gathered in Tasks 1 through 3 of the study plan.

5.0 FEATHER RIVER FLOODPLAIN AND WATER SURFACE PROFILES

5.1 INTRODUCTION

DWR required new floodplain mapping, compatible with the USACE hydrology of the Yuba-Feather system which was updated in 1999. The immediate purpose was to support DWR's effort to relicense the Oroville Facilities with the Federal Energy Regulation Commission. However, it also filled a need for mapping for the Federal Emergency Management Agency (FEMA) flood insurance program. The mapping studies were performed to FEMA standards to make the product acceptable for use in flood insurance rate maps and for other FEMA-related purposes (pers. comm., Cheng, 2003).

This report briefly relates the conditions of the mapping studies, the participants, the input data and the method of conducting the studies. The report contains background information, a short description of the study and an orientation map embedded in the text. Appended are a key map, three foldout sheets of water surface profiles, and 12 sheets of floodplain/floodway maps.

5.1.1 Background Information

DWR requested assistance from the Sacramento District of USACE to prepare floodplain mapping studies along the Feather River. The purpose of the studies is to provide floodplain mapping for the Feather River from Oroville Dam to the mouth of the Feather River at the Sacramento River. USACE completed a draft of the upstream portion, from Oroville Dam to the mouth of the Yuba River, in 2002. The downstream study draft, from the Yuba to the Sacramento, is expected to be completed by December 2004.

New concerns about levee stability, incorporated in the downstream study, are requiring reassessment of the upstream study. It is expected that a reassessment study will begin in fiscal year 2005-06.

5.1.1.1 Statutory/Regulatory Requirements

FEMA manages the National Flood Insurance Program (NFIP). In California, DWR is a Cooperating Technical Partner with FEMA in supporting this program. As part of the partnership agreement, DWR has supported these detailed floodplain studies for the Feather River using NFIP standards. The studies are compatible with NFIP standards for preparing flood insurance rate maps (pers. comm., Christensen, 2003).

5.1.1.2 Study Area

The upstream study reach includes parts of Butte, Sutter, and Yuba Counties. From Oroville Dam downstream for about 24 river miles the river is in Butte County. For the next mile downstream, to Honcut Creek, the river divides Butte and Sutter Counties, with Sutter on the west and Butte on the east. From Honcut Creek 19 miles to the mouth of the Yuba, the Feather River divides Sutter and Yuba Counties, with Sutter on the west and Yuba on the east. Major communities along the Feather River in the study area include Oroville, Biggs, Gridley, Live Oak, Yuba City, and Marysville. Oroville lies just downstream of the Oroville Dam on the east side of the river. Biggs, Gridley, and Live Oak are located west of the river further downstream. Finally, at the end of the upstream study reach where the Yuba River joins the Feather, Yuba City is on the west and Marysville is on the east. The downstream study reach begins at that point, dividing Yuba and Sutter Counties for the next 15 miles to the Bear River and then crossing Sutter County for 12 miles to the mouth. The community of Nicolaus lies east of the Feather River about three miles south of the Bear River. Figure 5.1-1 illustrates the study areas. (USACE 2002a).

5.2 METHODOLOGY

5.2.1 Study Design

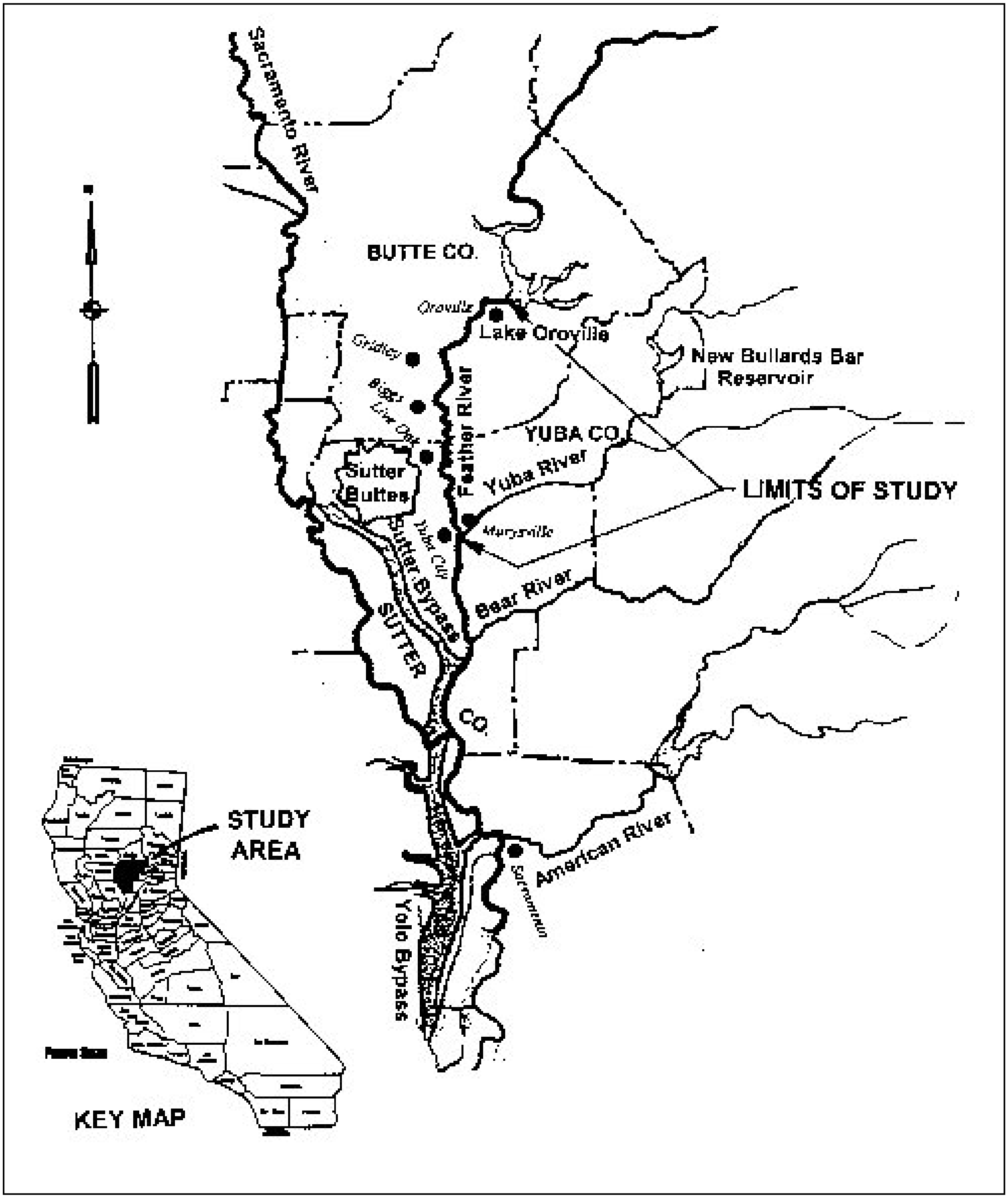
The upstream study modeled flows in the Feather River from Oroville to the Yuba River for flood events having a 10%, 2%, 1%, and 0.2% chance of occurring in any year, to obtain water surface profiles (backwater curves), floodplain boundaries for the 1% (100-yr) and 0.2% (500-yr) floods, and floodway limits for the 1% flood.
The downstream study is modeling the same frequencies of events and will produce the same types of data. Detailed information about the downstream study will be available when the study is completed.

5.2.2 How and Where the Study Was Conducted

The Sacramento District, USACE, conducted the upstream study in Sacramento using the three computer programs described below.

Input data to the study included:

- Feather River inflow hydrographs from the Comprehensive Study;
- Local inflow hydrographs from the Comprehensive Study, including the Yuba River, Honcut Creek, Jack and Simmerly Sloughs, and Deer Creek;
- Topographic data from the Comprehensive Study, surveyed in 1999, including digital terrain models and two-foot contours;
- Bridge plans from the California Department of Transportation;
- Plans for Oroville Facilities structures from DWR;



Source: USACE 2002b.

Figure 5.1-1. Study Area and Limits.

- Aerial photos from the Comprehensive Study and U.S. Geological Survey (USGS) quad maps used as bases for floodplain maps;
- Manning's n-values determined from aerial photography and field observation, sensitivity tested to assess the validity of n-value selections.

The upstream study, using the Comprehensive Study hydrographs, routed flows both with XRATE, a composite hydrologic routing and hydraulic rating program that accommodates levee breaks and weir flow and with HEC-RAS, the one-dimensional steady/unsteady flow program of USACE's Hydrologic Engineering Center (HEC). XRATE was used primarily to route flows through the Feather River system; HEC-RAS was used, in the steady-state mode, to determine water surface profiles in the main river and some overbank areas. The results of XRATE and HEC-RAS were compared and input flows and storage losses were adjusted to make the results of the two models reasonably consistent. The study also used XRATE to model overbank storage around Oroville, but used FLO-2D to model the large right bank overflow area.

Form loss and boundary conditions were covered by close coordination between cross section data, aerial photography, and observations in the field. Starting water surface elevations were based upon normal flow depth at the mouth of the Bear River, an adequate distance downstream of the study reach so that the normal depth assumption would not affect the study reach.

Water surface elevations for overflow areas near Oroville were determined based upon overflow ratings of the flow leaving the overflow area, using either Manning's equation or the weir equation as appropriate.

When modeling was complete, the modeled water surface was compared to the existing ground surface. Flood boundaries were located at the intersection of these two surfaces and adjusted for reasonable smoothness and elimination of discontinuities. This was done with 2-foot contour maps from the Comprehensive Study topography, except that overbank areas from River Mile 64 to River Mile 56 were drawn using USGS contour maps. The left overbank area from River Mile 56 to River Mile 55 is based on backwater from the main river channel. This was done with the use of 2-foot contour maps. This area and other areas near Highway 70 were field checked (USACE 2002a).

5.3 STUDY RESULTS

The upstream study delineates the 10%, 2%, 1%, and 0.2% flood profiles, the 1% and 0.2% flood boundaries, and the 1% floodway. It was prepared using FEMA standards for study contractors preparing information for flood insurance rate maps.

The USACE study report contains ten foldout water surface profiles on scales of 1" = 2000' horizontally and 1" = 10" or 1" = 20' vertically and nine 36"x44" maps at 1" = 1000' delineating the floodplains and floodway. The floodplain/floodway maps are based on aerial photographs where available from the Comprehensive Study, or USGS. quad maps in other areas. Appendix A of this report includes a reduction of that data, including three half-scale 11”x17” profiles and 12 quarter-scale (1” = 4000’) floodplain maps on a quad map base. Figure A-1 is a key map for the profiles and floodplain maps.

Floodplain/floodway maps and water surface profiles for the downstream study will be available when the study is completed.

5.3.1 Floodplain Delineation

The floodplain for the upstream study represents the maximum extent of inundation for the event depicted, either the 1% flood or the 0.2% flood. For both the 1% and the 0.2% flood event, water crosses Highway 70 at several locations. These locations are noted on the maps but are not delineated because of possible flooding from other sources that were not studied.

Backwater effects of the Feather River for Honcut Creek are noted but not shown because there has been no detailed study on Honcut Creek, which could have a significant effect on the extent of the floodplain. Backwater effects on Jack and Simmerly Sloughs are also not shown, but previous studies showed that the sloughs’ water profiles are dependent on Feather River backwater. The condition is noted on the maps.

Flood boundaries shown south of the West Interception Canal and west of the Wadsworth Canal are not based completely on the modeling, which did not cover this area. The modeling of the 0.2% flood showed that in the southeast corner of this area (where the Sutter Bypass and Wadsworth Canal join) there are considerable water depths. The water surface elevation for the rest of this area is based upon these depths and no analysis, and should therefore be considered approximate (USACE 2002a).

5.3.2 Floodway Delineation

The floodway developed and depicted on the maps is that portion of the flowage area that must remain free of encroachment to avoid exceeding a one-foot rise in water surface (FEMA 2001). The location of the floodway was developed because it is of particular interest to FEMA.

To meet the FEMA standards for floodways:
- The floodway must be based on the 1% flood.
- The width of the entire flowage area is assumed to be reduced by encroachments to derive a floodway that flows not more that one foot deeper that the unreduced width. (This is the “one-foot surcharge” condition.)

- Where the floodway can be encroached on both sides, it must be done so that equal volumes of flow are cut off on each side (This is the “equal conveyance reduction” condition.) (FEMA 2001).
- No encroachment is usually allowed beyond the top of bank or top of levee because of high velocities and erodible materials (pers. comm., Christensen 2004).

From Oroville Dam downstream to State Highway 70 (about six miles) the channel is well defined with steep slopes. The floodway in this section of the river was therefore drawn the same as the 1% floodplain boundaries with the exception of a few locations where the floodway boundary excludes small storage areas that do not convey flow. These areas were not included in the HEC-RAS model and therefore their elimination from the floodway does not increase the computed water surface profile (USACE 2002a).

For about two miles downstream from Highway 70, encroachment analysis was performed using equal conveyance reduction. To comply with the NFIP floodway criteria, most cross sections in this reach did not have a one-foot surcharge. Because there is little or no right overbank flow in this section of the river, most of the width of encroachment occurred in the left overbank area (USACE 2002a).

A floodway is not applicable for the next seven miles, to 15 miles below Oroville Dam, because of the multiple locations of split flow through the extensive dredger tailings southwest of Oroville (USACE 2002a).

From 15 miles below Oroville Dam to Honcut Creek, equal conveyance reduction was not applicable because the existing levee is the right floodway boundary and only the left overbank area can be encroached. Determining the floodway in this reach proved difficult because the flow remained in the channel at some cross sections and at others it did not. The maximum surcharge at any cross section within this reach was one foot, though for relatively smooth hydraulic transitions not all sections reached the maximum (USACE 2002a).

The floodway below Honcut Creek is shown along the levees, which are continuous on both sides of the river to the end of the study reach at the Yuba River (USACE 2002a).

5.4 ANALYSES

Current concerns about the applicability of levee certification for the upstream study require reassessment of the study. USACE levee certification criteria have become more stringent, addressing concerns by the USACE Levee Task Force and new issues including potential erosion sites. The reassessment study is planned for fiscal year 2005-06 pending expected State funding for this effort. The major concern is with the assessment of the levee systems for potential failure during a 100-year event.

The floodplain studies will produce floodplain boundaries consistent with the NFIP flood insurance requirements. There are additional considerations in preparing floodplain boundaries for development of flood control projects. A study for the purpose of project development should be based on levee stability functions and failure conditions derived from all available geotechnical data, or new data where existing data are insufficient. It should also include floodplain studies of the Yuba River and Honcut Creek, should investigate sources of flooding east of Highway 70 in the Oroville area, and should address any approximations made in the downstream study, if the floodplain boundaries in the affected locations are germane to the project.

For the Comprehensive Study, the likely failure point of the levees was developed from geotechnical data, extensive interviews with levee district personnel, and best engineering judgment (USACE 2002a). In the Feather River area, an intensive search for additional geotechnical data was conducted for the SCFS (pers. comm., Fakes, 2003a). The search provided extensive additional data and resulted in improved estimates of levee stability in the SCFS (pers. comm., Fakes, 2003a). In these floodplain mapping studies, however, FEMA levee criteria were used in order to produce acceptable results for flood insurance rate maps. Under FEMA rules, the levee is considered breached when the water surface elevation reaches within three feet of the crest of the levee (FEMA 2001). This criterion potentially could produce a floodplain boundary quite different than that based on available geotechnical data.

Flows contributed by the Yuba River, taken from the Comprehensive Study, do not result from a detailed study of the Yuba River. It is generally believed the Yuba River would not convey either the 1% or the 0.2% flood event down to the Feather River because of the likelihood of a levee breach on the Yuba River.

There has also been no detailed study of Honcut Creek (USACE 2002a). Such a study could result in significant changes in the floodplain boundary in that area (USACE 2002a).

6.0 FORECAST BASED OPERATION OF OROVILLE DAM

6.1 Introduction

This report describes the status of forecast-based operations (FBO) and forecast-coordinated operations (FCO) on the American, Feather and Yuba Rivers. On the American River, HEC and Utah State University are consulting with the U.S. Bureau of Reclamation (USBR) in studies and model development to assess the effectiveness and determine means of implementing FBO at Folsom Lake. On the Feather and Yuba Rivers, the firm of MBK Engineers and Utah State University are assisting YCWA to study and model FBO/FCO for Lake Oroville and New Bullards Bar Reservoir. The studies and modeling seek to determine whether FBO/FCO can be used effectively to improve emergency operations and what the costs will be to reservoir water supply and other project benefits.

Concurrently with the river studies, the National Weather Service (NWS) California-Nevada River Forecast Center (CNRFC) has improved its river forecasting equipment and techniques significantly in recent years and has re-emphasized main stem river forecasting. For NWS, the University of San Diego/Scripps Institute of Oceanography is developing new systems of developing synthetic inflow forecasts that will provide the ability to synthesize forecasts having the characteristics of historical river flows.

This report describes the input data, methodology, and results to date of studies in the two areas. It includes background information, constraints, details of the studies, conclusions reached on the effectiveness of FBO/FCO, and a work plan for implementing FCO on the Feather and Yuba Rivers. There are four embedded figures and four embedded tables. No material is appended.

6.1.1 Background Information

6.1.1.1 Statutory/Regulatory Requirements

Flood management in Central California uses reservoirs, levees, bypass systems, and non-structural techniques to reduce the danger and extent of flood damage. Prominent among these are the reservoirs on major streams as the exit from the mountainous areas. USACE participated technically and financially in the development of these reservoirs under its flood control mission. The reservoirs have seasonal flood control space reservations. The reservoir operators (principally USBR, USACE itself, DWR, and water districts) manage these reservations under the regulations of USACE. Any modification of reservoir flood control procedures is subject to USACE approval.

6.1.1.2 American River Study Area

The USBR American River studies extend from the mouth of the river at the Sacramento River to Folsom Lake. Figure 6.1-1 depicts the study area.

Description

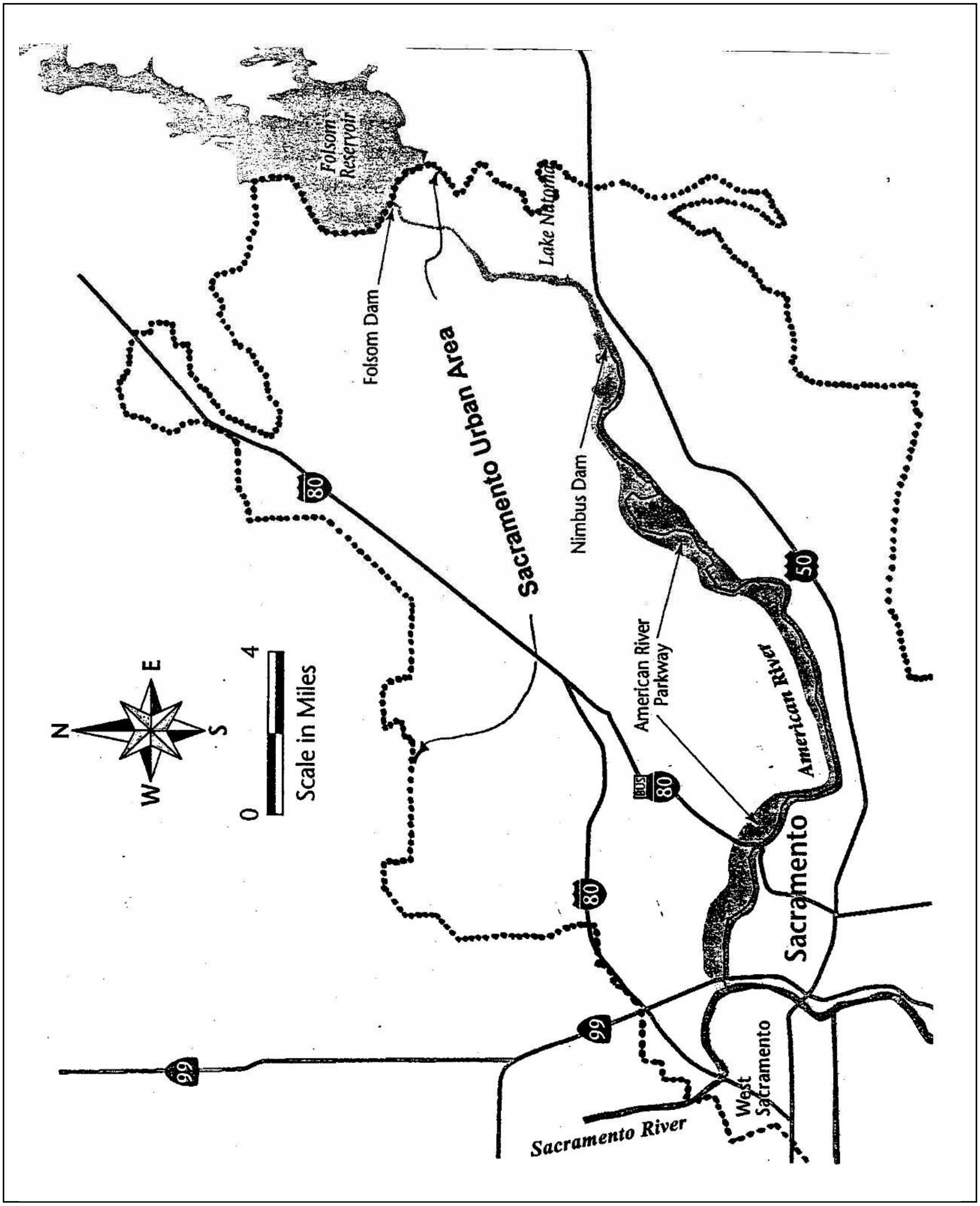
The American River is a principal tributary of the Sacramento River. It originates in the central Sierra Nevada west of Lake Tahoe and flows generally southwesterly. At the western edge of the Sierra foothills, the river is regulated by Folsom Lake, a reservoir with a capacity of 977 taf and a flood control reservation varying from 400 to 670 taf. Folsom Lake is located just upstream of the Sacramento urban area. From Folsom Lake the river environs are continuously urbanized for 30 miles to the mouth. Folsom Lake is the only reservoir on the American River to which FBO would apply.

History

USACE's 1991 American River feasibility study, undertaken in response to the 1986 flood, considered a variety of measures to improve flood protection on the American River. One such measure was releasing stored water from Folsom Reservoir before major storms based on river forecasts by the CNRFC. USACE rejected this measure because of insufficient reliability of the forecasts. The report cites difficulties in converting the NWS quantitative precipitation forecast to Folsom inflow; lack of forecast reliability for a period of more than six hours; potential liability for damages when releases exceed inflow; lengthy time required to calculate actual inflows; flow rate constraints imposed by the Folsom outlet works; time required to adjust outlet gates; and reluctance to jeopardize water supplies. The study recommended a flood detention dam at Auburn (USACE 1991).

Congress sent the concept back for further study. In response USACE first produced an alternatives report for the Sacramento community to use in identifying a locally preferred plan for flood protection as input to the feasibility study. USACE considered a variety of flood control measures, some included in the 1991 study and some new. The concept of advance releases using FBO was reconsidered but not offered as a choice to the community, again citing the unreliability of the current art of inflow forecasting. Several of the same reasons given in 1991 were reiterated in rejecting FBO in 1994 (USACE 1994).

The 1996 feasibility report supplements the 1991 report. The 1996 study again examined various flood control measures, including "early flood releases based on weather forecasts" (advance releases determined using FBO). This technique was again rejected, based on the uncertain accuracy of the forecasts and potential loss of water supply. The 1996 study produced three alternatives. Two would have modified



Source: SAFCA 2000.

Figure 6.1-1. American River study area.

Folsom Dam and the downstream levees physically and operationally. The third and recommended alternative was a flood detention dam at Auburn and again Congress rejected the plan (USACE 1996).

In February 1997, American River forecasters at CNRFC began to employ a revised algorithm for forecasting Folsom inflow, subdividing the watershed into four major segments, and instituted an improved version of the river simulation model. Concurrently, USBR, the dam operator, contracted with Utah State University to develop a Reservoir Release Forecast Model (RRFM) that would process stochastic forecasts of inflow to Folsom Lake to obtain the probability distribution of releases. Deterministic components of the Folsom RRFM are now operational at USBR and stochastic components are being tested at Utah State (USACE 2003a).

New modeling tools are being developed for the CNRFC that will enable construction of a series of forecasts corresponding to the historical sequence of American River flows (pers. comm., Hartman, 2003).

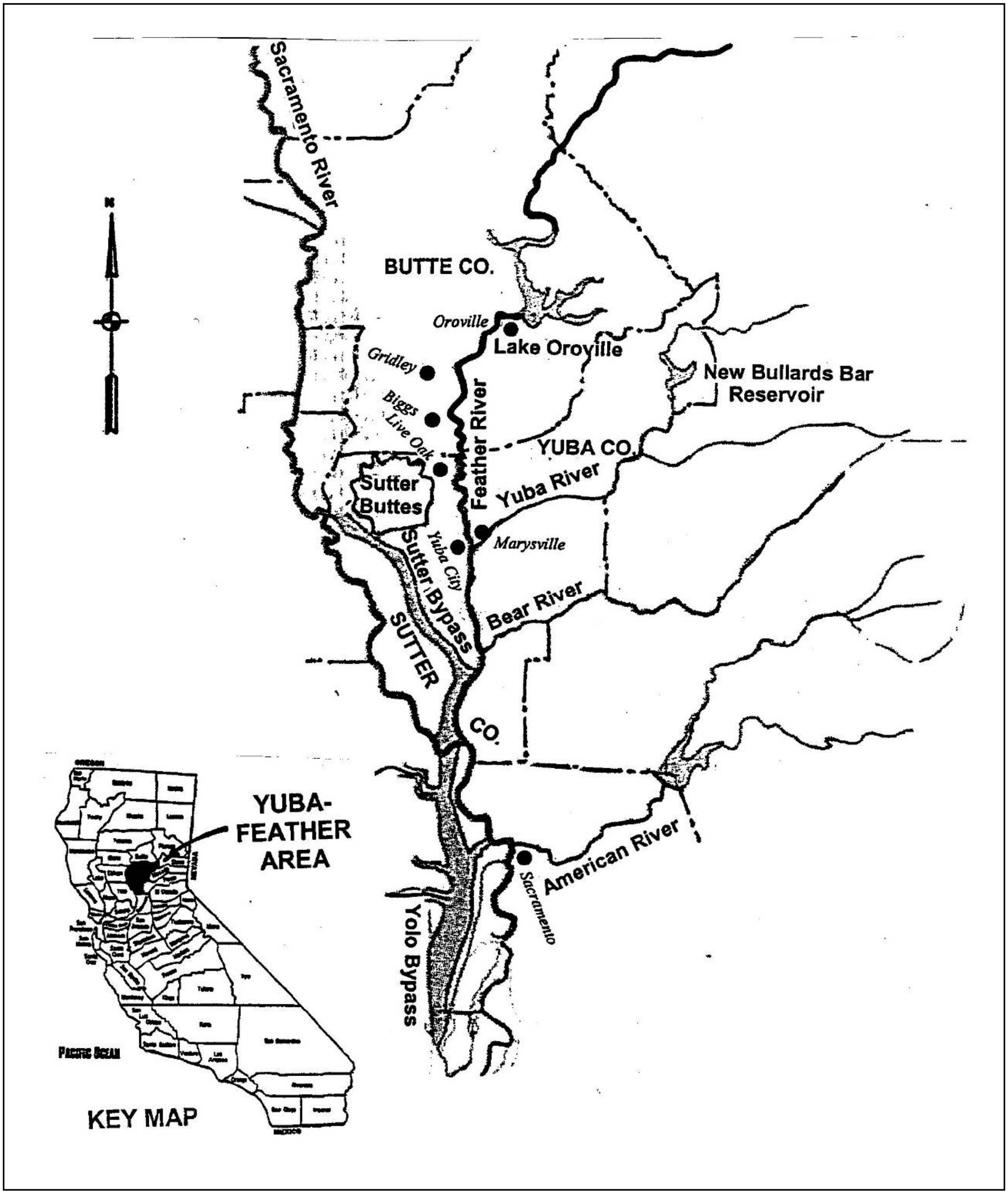
The 1999 federal Water Resources Development Act authorized the Folsom Dam Modification Project, which USACE is now pursuing. The project includes modifying the dam's outlet gates and update of the 1995 Folsom Dam Flood Management Plan to accommodate both the capabilities of the improved outlets and the potential of improved NWS forecasts. The USACE plan of study for the project includes reconsidering FBO. To begin this reconsideration, HEC performed the November 2002 study *Forecast-Based Advance Release at Folsom Dam: Effectiveness and Risks - - Phase 1*. The study is predicated on the outlet modifications at Folsom Dam. HEC concluded that with the modifications FBO could substantially improve the reservoir's flood protection capability (USACE 2003a; HEC 2002).

6.1.1.3. Feather and Yuba Rivers Study Area

The YCWA studies on the Feather and Yuba Rivers encompass the Feather River from just below the confluence with the Bear River upstream to Lake Oroville and the Yuba River from its mouth at the Feather River to New Bullards Bar Reservoir on the North Yuba River. Figure 6.1-2 shows the Feather-Yuba study area.

<u>Description</u>

The Feather is a principal tributary of the Sacramento River, entering it in Sutter County about 15 miles above the Sacramento urban area. The Yuba is tributary to the Feather in the area treated in this discussion. Both originate in the northern Sierra Nevada. The Feather River is regulated in the Sierra foothills by Lake Oroville, with 3,538 taf capacity and 375 to 750 taf flood control reservation. New Bullards Bar Reservoir regulates the North Yuba River. It has a capacity of 966 taf and a flood control reservation of 170 taf. The Middle and South Yuba Rivers have no flood control regulation.



Source: USACE 2002.

Figure 6.1-2. Feather-Yuba study area.

History

Consideration of FBO and FCO on the Feather River is being pursued as part of YCWA's YFSFCP. YCWA is preparing a feasibility study using a State grant under the YFFPP. Among the options being studied are physical and operational modifications at Lake Oroville and New Bullards Bar Reservoir. YCWA's operations studies include FBO at both reservoirs. These studies are reported in the draft feasibility study report that is being prepared and are summarized below. A separate consideration is FCO, a procedure seeking to improve the coordination of Oroville and New Bullards Bar operations. FCO is also reported in the draft feasibility study report and summarized below (YCWA 2002a; YCWA 2003).

Operators of Lake Oroville and New Bullards Bar Reservoir now coordinate informally on flood operations, including advance releases, but FCO would seek to formalize the procedure and optimize its benefits, ultimately implementing formal changes in the USACE operating rules for both reservoirs (YCWA 2003).

6.1.1.4 Role of the National Weather Service

The NWS CNRFC has achieved steady improvement in river forecasting techniques since the 1986 floods, and particularly since 1996. The NWS implemented a nationwide overhaul in the mid-1990s, acquiring new offices, equipment, and techniques throughout the country. The CNRFC in particular has redirected its efforts from former emphasis on better forecasts for unregulated fast-running streams, such as California coastal rivers, to improving main-stem river forecasts, particularly the Sacramento River system.

The NWS has contracted with the Hydrologic Research Center of the Scripps Institute of Oceanography (HRC) in San Diego to develop a system for synthesizing inflow forecasts using the current procedures and skill levels of the CNRFC (pers. comm., Hartman, 2003).

6.2 METHODOLOGY

6.2.1 Study Design

This report is a summary of efforts to develop, assess, and apply FBO and FCO to two river systems, the American River and the Feather River-Yuba River system. Release of stored water from reservoirs in advance of an impending storm is the principal method of FBO. Joint operations planning and increased interagency cooperation are the key features of FCO. The report describes efforts in four areas.

- The Folsom Dam Modification Project, a flood control project of USACE, will consider FBO in developing an advance release plan for Folsom Lake (USACE 2003a).

- The USACE HEC Folsom Advance Release Study studied methods of applying FBO to Folsom operations and conditions under which FBO would be beneficial. Phase 1 of the study, involving numerous model runs, is complete and has identified additional work necessary in succeeding phases (HEC 2002).
- The YCWA YFSFCP, now in the feasibility study stage, proposes to make changes in facilities and operations, including the application of FCO and potentially FBO at the Oroville Facilities and at New Bullards Bar Reservoir (YCWA 2002; YCWA 2003).
- The NWS has improved its forecasting capabilities and is developing models to provide further technical advances, making the available weather forecast a more reliable component of FBO. The CNRFC has placed new emphasis on forecasting Sacramento River flows (pers. comm., Hartman, 2003).

6.2.1.1 Folsom Dam Modification Project

The Folsom Dam Modification Project includes enlarging eight river outlets, constructing two new outlets, modifying dikes and spillway gates at the dam, and updating the flood management plan. A sub-component of the project is to prepare an advance release plan. The objective of the advance release plan will be to provide operational flexibility leading to better optimization of flood control, water supply, and other objectives. The flexibility would be attained by modifying the flood control diagram to allow advance releases using NWS inflow forecasts (USACE 2003a).

The circumstances that make a reconsideration of FBO reasonable are:
- The development of the Folsom RRFM, which will enable preparation of stochastic inflow forecasts, both on a real-time operational basis and in a study mode (USACE 2003a);
- The HRC forecast synthesizing tools (USACE 2003a);
- The HEC modeling of FBO strategies, begun in the 2002 phase 1 advance release study (HEC 2002);
- Modification of the Folsom Dam outlets to allow larger releases at low water elevations (USACE 2003a);
- Restricting FBO to only very large storm forecasts (pers. comm., Bowles, 2003).

6.2.1.2 HEC Folsom Advance Release Study

USBR now performs flood operations at Folsom Reservoir under USACE rules, based on current inflow and calculated inflow in the immediate future based on actual upstream flow and precipitation. The outstanding unused available data are CNRFC 3- to 5-day inflow forecasts prepared using forecasted precipitation. HEC developed procedures for advanced release operations using these data and tested the procedures' effectiveness. HEC recognized two reservoir purposes other than flood protection: water supply and hydropower generation. They studied the effects of FBO from the standpoint of the impact on reservoir storage, since its maximization is a benefit to both additional purposes.

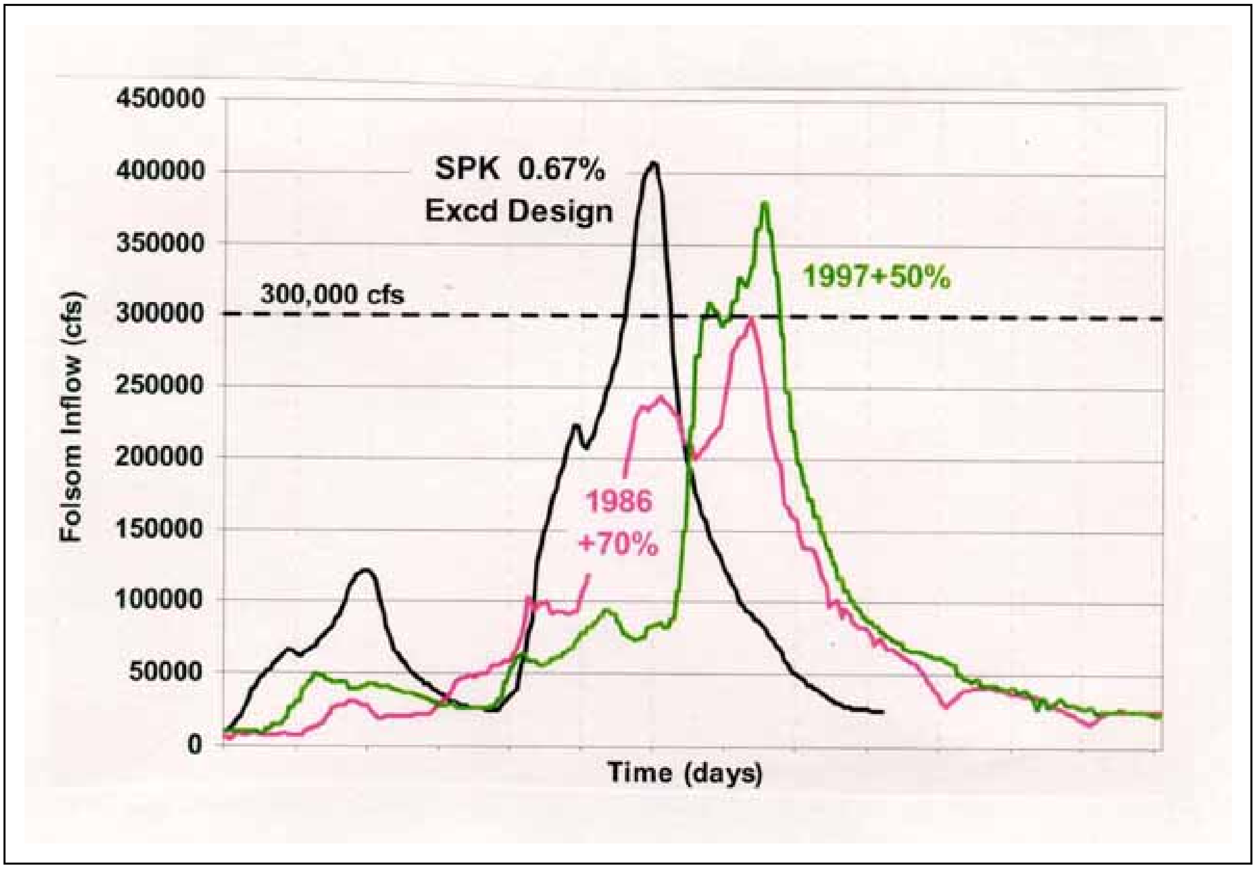
HEC defined a very large event at Folsom as an inflow event that would produce a discharge of more than 115,000 cfs (the “safe” downstream flow rate) without an advance release. A large event is defined as one that would produce a maximum of 115,000 cfs with no advance release, but for which, with advance release, the reservoir would still refill during the event. In a small event, advance release would preclude reservoir refill during the event. HEC modeled the situation in which a very large event is forecasted and occurs, observed that any combination of forecasted and actual large event or small event would not require advance release, and noted without thorough study the possibilities of a forecasted very large event and an actual large event (a “false alarm” in which advance release causes neither increased damage nor reduced water supply); a forecasted very large event and an actual small event (a “false alarm” having potential for reduced water supply); and a forecasted large or small event and an actual very large event (potential benefit of advance release not realized). Table 6.2-1 illustrates these combinations. HEC identified forecast period, release flow rates, starting trigger, and discontinuing trigger (for “false alarm” forecasts) as critical parameters of any advance release strategy.

Table 6.2-1. HEC Folsom study - Combinations of forecasted and actual events.

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="3">Forecasted Event</td></tr>
<tr><td>Very Large</td><td>Large</td><td>Small</td></tr>
<tr><td rowspan="3">Actual Event</td><td>Very Large</td><td>Included in HEC study</td><td colspan="2">“Missed Opportunity”--Potential flood protection benefits not realized</td></tr>
<tr><td>Large</td><td>“False Alarm”--Advance release has no effect</td><td colspan="2" rowspan="2">Advance release not appropriate</td></tr>
<tr><td>Small</td><td>“False Alarm”--Potential reduced water supply</td></tr>
</table>

Source: HEC 2002.

In the model studies, HEC used artificially generated forecasts based on statistics of actual forecasts at the CNRFC during the December 23, 1996-January 4, 1997 flood event. No flood events have occurred since then that would provide an appropriate sequence of forecasts. Because there are no records of occurrences of a very large flood on the American River, “actual” hydrographs were derived using 170% of the 1986 flood inflows, 150% of the 1997 event, and USACE’s 0.67% exceedence design storm. These are illustrated in Figure 6.2-1.



Source: HEC 2002.

Figure 6.2-1. Storms used in HEC Folsom study.

HEC developed and studied two methods of determining the release flow rates: the “increment-based” strategy that adds a fixed increment to actual inflow and the “volume-based” strategy that would ideally result in refilling the reservoir at the instant the inflow drops below the “safe release” of 115,000 cfs. The increment-based strategy (IB) requires increasing the reservoir outflow to be a fixed amount greater than the current inflow. (The studies use 25,000 cfs, 50,000 cfs, and 75,000 cfs.) The volume-based strategy (VB) employs a selected probability that the reservoir will refill. (The studies calculate the advance release volume using the inflow volumes having 50%, 60%, 70%, 80%, 90%, 95%, and 99% probability of exceedence.) VB requires reiterating the routing calculations and adjusting the flow rates every six-hour forecast period.

All of the reported simulation runs used an initially empty flood pool assumed to be 500,000 acre-feet, equivalent to an initial storage of 477,000 acre-feet.

The two strategies are initiated or discontinued by trigger events. Several alternatives are described in the study. The HEC model studies investigated two different starting trigger mechanisms: 1) either a forecasted peak inflow rate of 300,000 cfs or a forecasted inflow volume of 1,000,000 acre-feet and 2) a calculated peak release volume of more than 115,000 cfs without advance release. Discontinuation triggers were not needed in the model runs, since they simulated only forecasts with accurate flood magnitude categories.

HEC performed simulations using the three events, two strategies, and two triggers described above. Two or three increments were used in the IB runs, amounting to14 different operational scenarios. The seven refill probabilities were considered in the VB runs, giving 42 operational scenarios. For each scenario, HEC performed model runs with 120 different simulated forecasts (HEC 2002).

6.2.1.3. Yuba-Feather Supplemental Flood Control Project

YCWA's consultant, MBK Engineers, performed operations studies throughout the region that includes control points for Oroville or New Bullards Bar flood operations; *i.e.*, from the dams to just below the Bear River on the Feather River. The studies modeled the existing physical plants and USACE-mandated operations and examined a number of combinations of measures including operations revisions, reservoir surcharges, modification of outlets, operation of Thermalito Afterbay, and FBO. The studies used a range of deterministic inflow hydrographs representing 15 storms from that having 1% annual exceedence probability to that with 0.2% probability. All studies began with the flood reservations empty. Oroville flood reservation, which varies according to the antecedent precipitation, was taken to be 750 taf (YCWA 2002).

MBK Engineers and Utah State University, YCWA's consultants for FCO, have proposed a four-phase approach that will require an estimated four years to implement. The consultants emphasize that FCO is not equivalent to FBO. FBO seeks to improve flood operations at an individual reservoir by implementing advance releases determined by inflow forecasts. FCO will coordinate reservoir operations in an environment of two reservoirs operated by different governmental agencies on different rivers but held to common control parameters under substantial uncertainty introduced by unregulated streams. FCO will probably incorporate FBO techniques, but the wider concept also embraces measures such as improving communications between emergency managers and improving information sources. FCO will seek to guide operations toward optimization of the total benefits of both reservoirs initially using a deterministic operations RRFM, an unsteady flow routing model, and ultimately additions to the Feather and Yuba watersheds' telemetered hydromet network, stochastic additions to the operations RRFM and the routing model, and a planning version of the stochastic RRFM (YCWA 2003).

The RRFM would be similar to the Folsom RRFM, for which the deterministic operations version is in use at the USBR. Utah State University, developer of the Folsom model, has proposed to develop the Yuba-Feather RRFM (YCWA 2003).

6.2.1.4 National Weather Service

The NWS effort has not been a single designed study effort, but a national renewal of the organization's entire approach to providing weather services. It began in the mid-1990s with a new generation of electronic software and equipment for storm forecasting and construction of many new offices across the country. In Sacramento, the NWS weather forecasters and the CNRFC moved to remodeled offices adjacent to the DWR and USBR operations control centers for the SWP and the Central Valley Project.

A long-term effort at the CNRFC to improve river forecasting was renewed in 1996 and resulted in implementation of the state-space version of the Sacramento soil moisture accounting model for runoff forecasting (USACE 2003a). The current American River implementation divides the basin into three parts; prior to 1997, one or two sub-basins were used (pers. comm., Hartman 2003).

The CNRFC has begun a forecast improvement effort that will involve many consulting contracts on various aspects of forecasting and forecasting models. Currently, the CNRFC is contracting with HRC to develop a synthetic forecasting system. Such a system will incorporate the statistical characteristics of recently past CNRFC forecasts and will also take into account the aggregate skill level of the CNRFC as evidenced by existing forecast accuracy. The system will enable the CNRFC to synthesize great numbers of forecasts. CNRFC expects that the system will produce forecasts of "false alarm" events as well as other events and enable CNRFC to estimate the frequency of occurrence of such events (pers. comm., Hartman 2003).

Along with the efforts to improve weather and river forecasting, there is a new emphasis on forecasting main stem streams such as the Sacramento River. Until the mid-1990s, the CNRFC concentrated on improving forecasts of unregulated fast-running streams, such as California coastal rivers (pers. comm., Hartman, 2003).

6.2.2 How and Where the Studies Were Conducted

The Sacramento District, USACE, is preparing the Folsom Dam Modification Project. The Reclamation Board and the Sacramento Area Flood Control Agency are the non-federal sponsors. All three agencies are based in Sacramento, California. The project is about to enter the construction phase. The project operator is the USBR Central Valley Operations Control Office in Sacramento. Utah State University in Logan, Utah has consulted with USBR to develop the Folsom RRFM (pers. comm., Lerner, 2003).

The HEC Folsom Advance Release Study - Phase I has been completed by HEC at its Davis, California laboratory using USACE computer models (HEC 2002).

YCWA of Marysville, California is developing the YFSFCP. A feasibility study is currently being prepared with the assistance of MBK Engineers, Sacramento, California and Utah State University, Logan, Utah. The feasibility study is being supported by a DWR grant through its YFFPP. DWR has accepted portions of the feasibility study documentation, but the overall study is pending approval. YCWA has applied for a design grant through the same program and its application is pending (pers. comm., Yamanaka, 2003).

The various efforts of the NWS have been based in Washington, D.C. and, especially for the river forecasting improvements, at the NWS in Sacramento, California. The CNRFC is consulting with HRC (pers. comm., Hartman, 2003).

6.3 STUDY RESULTS

6.3.1 American River

6.3.1.1 Folsom Dam Modification Project

Design of the Folsom Dam Modification Project has been completed and Phase 1 of the development of advance release strategies was completed with the issuance of HEC's advance release study report in November 2002 (pers. comm., Lerner, 2003; HEC 2002). The schedule called for completion of the HRC forecast tools in September 2003, completion of the HEC strategy development in May 2004, inclusion of the strategies in an updated Folsom RRFM by March 2005, and final update of the Folsom Flood Management Plan by October 2006 (USACE 2003a). The project plan included a goal of pilot operation of Folsom Dam under a temporary advance release authorization as early as the flood season of 2003-2004 (USACE 2003a).

6.3.1.2 HEC Advance Release Study

HEC determined that recovering the advance release is essential to avoid adverse impact on water supply and generation. They also recognized that advance releases must not be accomplished at a higher peak flow rate than would have occurred under the present non-FBO operations. This requirement is to avoid the increase in flood damages that could occur at higher flows.

NWS river forecasts are available for 3-day and 5-day periods. The NWS advised HEC that the 5-day forecast would not be a reliable enough basis for operating decisions, but it would be reasonable to incorporate forecasted flows 3 days distant or less. The studies therefore use a forecast period of three days.

The model studies found little difference in results between the two trigger mechanisms, and little difference in results of the VB strategy for values of refill probability from 50% to 95%. The HEC report therefore concentrates on the 95% and 99% refill probabilities and does not discuss further the difference in results for different triggers. For the 13 remaining scenarios, Table 6.3-1 shows the drawdown volume, minimum storage, and maximum release averaged over the 120 simulated forecasts. The frequency (within the 120 forecasts) of exceeding the 115,000 cfs safe release is also shown and, for the IB strategy, average refill probability.

Table 6.3-1. Summary of HEC Folsom study simulation results.

Event	Strategy		Average drawdown, taf	Average minimum storage, taf	Average maximum release, kcfs	Frequency that release exceeded 115 kcfs	Average refill probability, percent
	Basis	Refill probability or increment					
150% of 1999	VB	99%	48	448	130	0.99	
	VB	95%	113	384	116	0.16	
	IB	25 kcfs	80	422	118	0.58	96.3
	IB	50 kcfs	120	382	116	0.13	95.0
170% of 1986	VB	99%	85	452	117	0.18	
	VB	95%	102	416	115	0.03	
	IB	25 kcfs	59	457	117	0.23	98.5
	IB	50 kcfs	92	424	115	0.01	97.9
Design storm with 0.67% probability of exceedence	VB	99%	136	380	127	0.83	
	VB	95%	181	336	115	0.04	
	IB	25 kcfs	37	468	179	1.00	99.0
	IB	50 kcfs	107	403	133	1.00	96.6
	IB	75 kcfs	138	376	115	0.00	95.7

Source: HEC 2002.

The average drawdown and frequency of exceeding the safe release are also illustrated in Figure 6.3-1. The variability of the average drawdown is a function of the shape of the event hydrograph; hydrographs with high early flow allow less drawdown. Therefore, a strategy cannot be readily evaluated on the basis of attained drawdown. Average drawdown is useful, however, in comparing scenarios using different parameters for the same event.

The frequency of exceeding safe release is probably the most pertinent statistic presented, since it gets to the heart of the matter of reducing downstream flood damage. Figure 6.3-1 clearly shows the correlation between lower refill probability (VB) or higher release increment (IB) and higher effectiveness measured by frequency of exceeding safe release. Also instructive are the maximum release rates that would be required under the present operating rules, with no advance release. Table 6.3-2 compares these to the average maximum release rates with advance release.

Table 6.3-2. Maximum release rate for present operating rules and average maximum release rates for selected FBO scenarios, American River.

Strategy	Event; release rate in cfs		
	150% of 1997 Event	170% of 1986 Event	0.67% Exceedence
Present rules	155,000	154,000	263,000
VB, 99% refill prob	129,947	116,929	127,083
VB, 95% refill prob	116,170	115,435	115,288
IB, 25,000 cfs incr	117,526	116,813	179,175
IB, 50,000 cfs incr	115,800	115,063	133,454
IB, 75,000 cfs incr	-----	-----	115,000

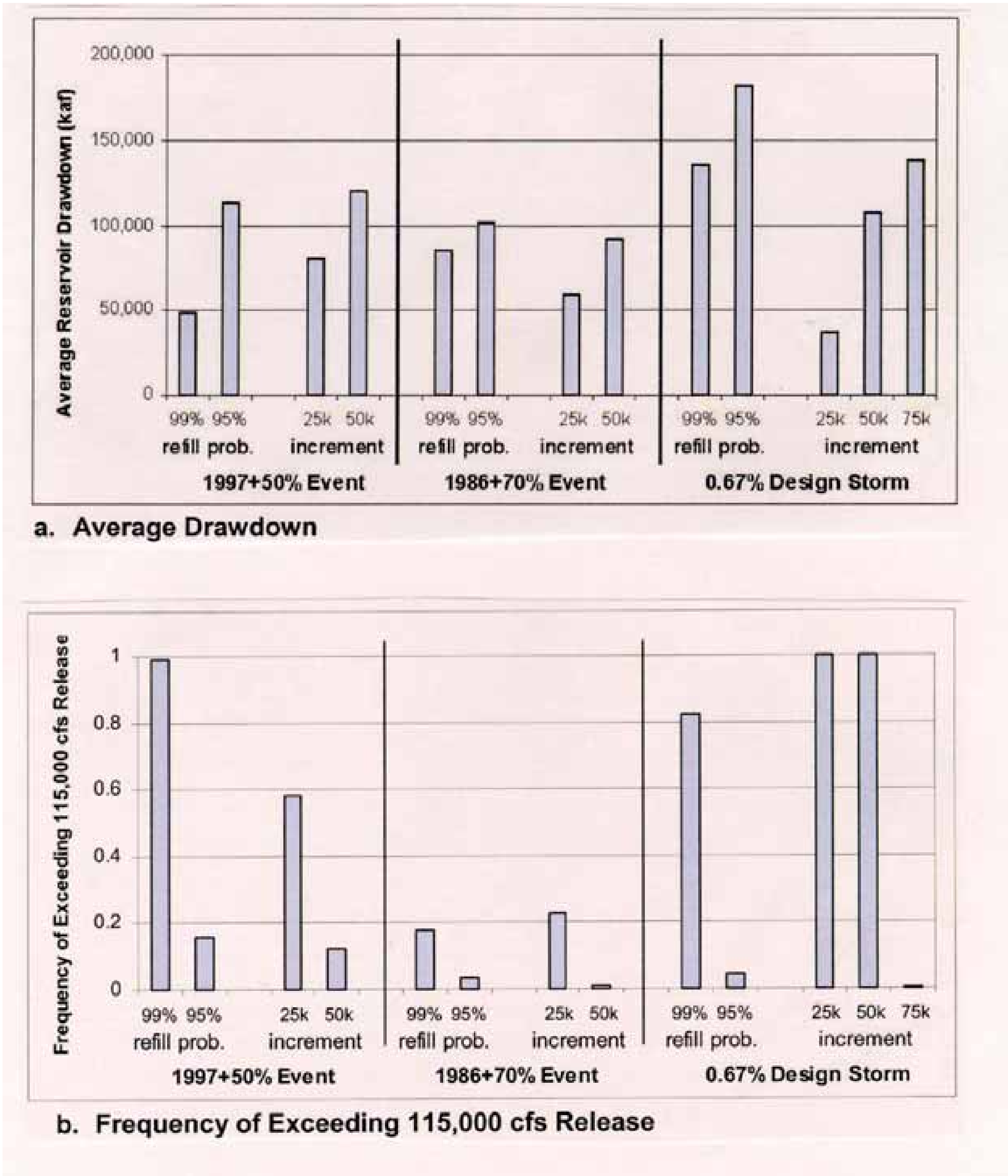
Source: HEC 2002.

VB = Volume based advance release strategy

IB = Increment based advance release strategy

HEC also investigated several other aspects of FBO:

- Tested sensitivity to incorrectly timed forecasts by simulating forecasts of peaks earlier and later than the event;
- Tested sensitivity to the forecast period by comparing the three day forecast results to results using only the first two days;
- Developed some preliminary ideas about using probabilities of seasonal refill rather than refill in the same event in the VB procedure;
- Commented on the possibility of varying the increment in the IB procedure, making it more responsive to the volume forecasted;
- Noted some other possibilities for trigger parameters (HEC 2002).



Source: HEC 2002.

Figure 6.3-1. HEC Folsom study - Results of streamflow forecast simulations.

6.3.2 Feather and Yuba Rivers

6.3.2.1 Yuba-Feather Supplemental Flood Control Project

YCWA is preparing the feasibility study report for the YFSFCP. DWR has received review drafts of the main report and most appendices. Appendix B, Flood Operations, and Appendix G, Forecast-Coordinated Operations, are considered final drafts awaiting overall approval of the study.

Appendix B reports in detail on the studies performed for the 0.57% exceedence event. Results pertinent to FBO for the 0.57% event are summarized in Table 6.3-3 together with assumptions made for the studies.

The FCO consultants, whose work is reported in Appendix G, have developed a four-phase approach:

Phase 1. - Enhanced Coordination under Existing Reservoir Operating Rules.

This phase will include development of the deterministic Yuba-Feather RRFM and an unsteady flow routing model for operations of both reservoirs under the existing USACE rules, improved information dissemination to emergency managers, and a capability of operations during blackouts. Operators would have the option of calculating and implementing alternative releases for the purpose of studying system response. The models would incorporate new or proposed physical or operational features as options for study purposes and these would be incorporated in the models as the features are implemented in the prototype. The RRFM and routing models would be linked to each other and interfaced with the CNRFC forecasting procedures. The consultants did not select software for this purpose but suggested consideration of the USACE HEC-RAS program.

Benefits of Phase 1 are expected to be better implementation of existing rules, more accurate forecasting, improved operator coordination of information and decisions, ability to consider alternate release scenarios, more timely emergency management information, and more predictable operation in blackouts.

Phase 2. - Improved Flood Forecasts.

This phase includes adding additional precipitation, snow, reservoir stage, and stream flow gages to the California Data Exchange Center telemetered real-time network and adapting the Yuba-Feather RRFM and routing model to use the new information. The result is expected to be reduced forecast uncertainty.

Table 6.3-3. YCWA Operations studies - Lake Oroville and New Bullards Bar Reservoir - Storm with 0.57% probability of exceedence.

Line	Operation	Oroville and Feather River							NBB and Yuba River					
		Alternate 9.7-foot surcharge	Thermalito drawdown	Forecast-based operation	Maximum outflow, kcfs	Duration of maximum outflow, hr	Maximum reservoir depth above spillway lip, feet	Maximum flow rate at Shanghai Bend, kcfs	10-foot surcharge	Increased outlet capacity	Forecast-based operation	Maximum outflow, kcfs	Maximum reservoir depth above full pool, feet	Maximum flow rate at Marysville, kcfs
1	Standard operation				152	110	2.2	354				98	2.6	216
2	Std op + FBO at Oroville				150	100	1.2	345						
3	Std op + FBO at NBB											98	2.6	214
4	Oroville surcharge + FBO				150	94	6.4	325						
5	Oroville + Thermalito + FBO				150	99	0.3	305						
6	NBB surcharge + FBO				150		0.9	288				59	11.3	173
7	NBB larger outlets +FBO				150		1.2	300				74	1.8	173
8	NBB larger outlets + surcharge + FBO				150		1.1	288				50	3.5	173
9	NBB larger outlets + NBB surcharge + Oroville surcharge + Thermalito + FBO				150		1.0	275				50	3.5	173

Source: YCWA 2002.

Legend:

Table shading — *Not used* (white) — *Unspecified or not applicable* (gray) — *Used* (black)

Standard operation	*Operation according to USACE regulations and current procedures at both reservoirs*
Std op	*Standard operation*
FBO	*Forecast-based operations*
NBB	*New Bullards Bar Reservoir*

Table 6.3-3. cont'd. YCWA Operations studies - Lake Oroville and New Bullards Bar Reservoir - Storm with 0.57% probability of exceedence.

Assumptions and parameters:
1. *Unregulated Yuba River flows below New Bullards Bar Reservoir are assumed 20% higher to compensate for forecast error.*
2. *Yuba River flow target is 180,000 cfs at Marysville. Studies assume that State will meet all other controls with Oroville outflow.*
3. *Advance releases under FBO at both reservoirs, when used, are triggered by 200,000 cfs inflow to Lake Oroville.*
4. *FBO is limited to developing 100 taf additional flood control space at the Oroville Facilities and 50 taf at New Bullards Bar Reservoir.*
5. *The forecast period for FBO is three days.*
6. *Maximum Oroville surcharge is 9.7 feet per Reference 1 on the Oroville emergency spillway release diagram.*
7. *Thermalito operation, if used, is 45 taf drawdown in advance of the storm.*
8. *Non-surcharges New Bullards Bar studies begin emergency releases at one foot above full pool.*
9. *Maximum New Bullards Bar surcharge is 10 feet.*
10. *Larger outlets at New Bullards Bar Reservoir add 20,000 cfs outlet capacity when reservoir is at the bottom of the flood space. They provide a 30% to 80% increase over the reservoir flood storage range.*

Source: YCWA 2002

Phase 3. - Implementation of Forecast Uncertainty and Development of FCO Procedures and Emergency Management Protocols.

The flood forecast, Yuba-Feather RRFM, and unsteady routing models would have stochastic capability added so that the ensemble can track forecast uncertainties, providing probability distributions for stages, flow rates, lead times for exceeding critical flow rates, and reservoir refill levels. A planning mode would be added to the RRFM, for off-line use in assessing alternative operating procedures. The planning RRFM would then be used to develop operating procedures and explore possible modifications to the operating rules. Emergency management protocols would be developed for using the new flood forecasts, now incorporating consideration of uncertainty.

Benefits of Phase 3 are expected to be improved capability for considering forecast uncertainty in normal and emergency operations and ability to test proposals for variations in operating procedure and emergency protocols.

Phase 4. - Implementation of Forecast Coordinated Operations.

In this phase, FCO procedures developed in Phase 3 would be incorporated in the operations version of the Yuba-Feather RRFM, resulting in improved coordination of operations, more effective floodway use with less risk of exceeding capacity, advance warning of capacity exceedence, and better information for emergency management (YCWA 2002; YCWA 2003).

6.4 ANALYSES

6.4.1 American River

6.4.1.1 HEC Advance Release Study

HEC concluded that there is significant flood protection benefit to be derived from FBO, though there remains some risk of failure to refill and of releasing in advance at a higher flow rate than would have otherwise occurred. They also pointed out that the benefits of FBO do not truly offset the costs, since the benefits accrue to those downstream of Folsom Dam and the costs of failure to refill are borne by water or power users over a wide area of the State. HEC identified storage encroachment into the flood control reservation in good weather as a potential mitigation for costs to water and power users, and earmarked the concept for further study.

The VB strategy tailors action to the event. It is susceptible to forecast error, but allows releases that are more effective. The IB strategy initiates incrementation upon forecast of a “very large” event, but uses no further information about the specific event, and thus is less susceptible to forecast error and less adaptable to the event.

In the VB strategy, the amount of drawdown that can be achieved is related inversely to the selected probability of refill, but the HEC simulations reveal that nearly all of the variability occurs at the high end of the probability scale. In the model runs, even a 90% probability achieves nearly all of the drawdown a 50% probability would. The inflow hydrographs for these studies were specifically selected to demonstrate this effect, but the results are expected to be similar for other events.

The HEC study admittedly does not provide a complete method of assessing the probability of either not realizing the available flood control benefits or causing losses to beneficiaries of the other reservoir functions. The principal reason is that it only tested very large event forecasts of very large events. A complete assessment of the probabilities would also include the situations where “false alarms” occur, or very large event forecasts are made followed by large or small events. Also, the “missed opportunity” situation must be assessed, where large or small event forecasts precede very large events.

Because the historical sequence contains no very large events, it will not be possible to assess the probability of “missed opportunity” forecasts. However, the CNRFC characterizes this occurrence qualitatively as unlikely. Very large storms are visible and detectable far across the Pacific Ocean. They are relatively stable in their movement and unlikely to develop suddenly or change course.

The CNRFC expects to find examples of “false alarm” forecasts using the forecast synthesizing system being developed at HRC. That will enable a better assessment of the probability of these infrequent occurrences.

The additional studies that are needed to conclude this investigation will use the Folsom RRFM being developed for the CNRFC at Utah State University. The RRFM will apply operating rules to simulate reservoir operation using a stochastic forecast leading to a probability distribution of release. The operating rules will include the current flood control diagram and emergency spillway release diagram and simulations may also employ the FBO strategies included in the HEC study (HEC 2002).

6.4.2 Feather and Yuba Rivers

6.4.2.1 Yuba-Feather Supplemental Flood Control Project

YCWA has found that uncertainties in the Middle and South Yuba river forecasts combined with restrictions on decreasing outflow rate from the Oroville Complex make it necessary to operate to less than the control point flowrates below the dams, particularly the control of 300,000 cfs just below the mouth of the Yuba River. FBO is cited as a way to operate probabilistically to the actual control point parameters and assess the risks of exceeding those rates.

As noted for the American River FBO considerations, YCWA’s consultant emphasizes the importance of ending each storm cycle with the reservoirs filled to the bottom of the flood reservation.

The YCWA simulations found that FBO at New Bullards Bar has no significant benefit unless the outlets are enlarged, as illustrated by lines 5 and 6 of Table 6.3-3. All New Bullards Bar studies except the base study on line 1 employ FBO. Some of these show significant benefits, but there are no comparisons reported between these studies and corresponding studies without FBO, so it is difficult to assess the value of FBO. The study also found that FBO benefits were limited by insufficient Oroville outlet capacity at lower water elevations (YCWA 2002).

7.0 YUBA-FEATHER SUPPLEMENTAL FLOOD CONTROL PROJECT

7.1 Introduction

This report describes the ongoing effort of YCWA to supplement flood protection efforts of USACE, The Reclamation Board, and local reclamation and levee districts to provide flood protection for the citizens of Yuba County. YCWA began planning and scoping studies for supplemental flood control program on the Yuba and Feather Rivers in 1997. The project eventually became known as the YFSFCP. In 1999, two legislative provisions materially affected the program: SB 496, which placed the South Yuba River in the California Wild and Scenic River System, and AB 1584, the Costa-Machado Water Act of 2000, which among other actions established the YFFPP. The YFFPP allocated $90 million for specified types of flood protection projects and related work on the Yuba and Feather Rivers and the Colusa Drain. The YCWA YFSFCP is a beneficiary of a feasibility study grant and a design grant under the program and is likely to be granted additional funds for design and construction.

The report includes background information, a description of the Yuba County area, a summary of the work done and results to date, and a short analysis. There are one embedded figure and one embedded table. No material is appended.

7.1.1 Background Information

7.1.1.1 Statutory/Regulatory Requirements

The Federal Power Act gives the Federal Energy Regulation Commission the authority to license power projects. On February 11, 1957, the Federal Power Commission, predecessor to FERC, issued a 50-year license effective February 1, 1957 to DWR to conduct and operate the Oroville Facilities (FERC Project No. 2100) (DWR 2003). This study provides information supporting DWR's preparation of relicensing documents.

To reduce the danger and extent of flood damage, flood management in Central California relies on constructed flood control works including reservoirs on major streams as they exit from the mountainous areas. These reservoirs have seasonal flood control space reservations. The reservoir operators manage these reservations under the regulations of USACE. USACE participated technically and financially in the development of Lake Oroville and New Bullards Bar Reservoir under its flood control mission. Any modification of reservoir flood control procedures is subject to USACE approval.

7.1.1.2 Study Area

Description

The Central Valley floor portion of Yuba County is bordered on the west by the Feather River, bisected by the Yuba River, and bounded on the south by the Bear River. Levees border most of the three rivers in this region. The levees have been constructed and reconstructed over many decades, but they have a history of catastrophic failure. In the last 53 years, levees on the Yuba and Feather Rivers have failed five times, resulting in the loss of 41 lives and significant property damage (YCWA 1998).

Lake Oroville, located on the Feather River about 4 miles northeast of Oroville in Butte County, provides up to 750 taf of flood control storage. On the North Yuba River, New Bullards Bar Reservoir has up to 170 taf of dedicated flood control space. The Middle Yuba River and the South Yuba River, which provide more than 60 percent of the Yuba Basin runoff, have no flood control reservoirs (YCWA 2003).

Figure 7.1-1 identifies the locations of the elements of the YFSFCP proposed for implementation under the YFFPP. It also shows most locations discussed elsewhere in this report and locates Yuba County within the State.

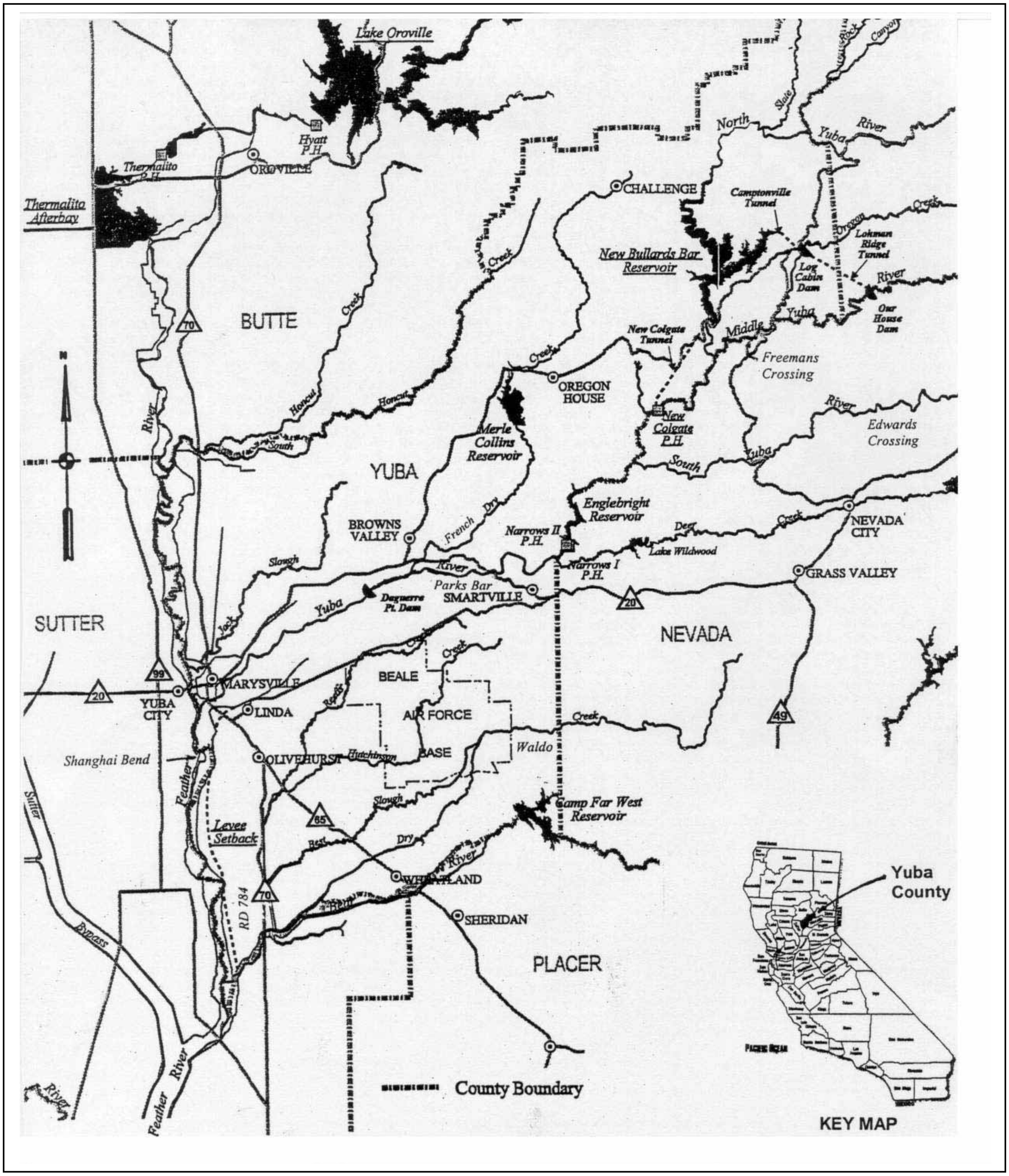
7.2 METHODOLOGY

7.2.1 Study Design

YCWA originally developed a seven-phase study program for improving the region's flood protection, as reported in their 1998 publication *Report on Phase I, Program Definition for Supplemental Flood Control on the Yuba River.* The seven phases are program definition, formulation and analysis of alternatives, planning for implementation of primary alternatives, conceptual design and regulatory consultation, environmental studies and permitting process, definite project formulation and permitting, and project implementation. To pursue the program, YCWA assembled a group of consultants headed by Bookman-Edmonston Engineering, Inc. At this stage, potentials for funding and partnership with other agencies were not definitely formulated (YCWA 1998).

7.2.2 How and Where the Studies Were Conducted

YCWA completed Phase I, Program Definition, in March 1998 and began work on Phase II, Formulation and Analysis of Alternatives, in 1998. The project purpose was stated to be "to define and implement as soon as possible a cost-effective, practicable program of measures to achieve a reliable level of protection against floods from the Feather and Yuba Rivers (YCWA 1998)." A reduction of 330 taf in peak flows exceeding 300,000 cfs at Shanghai Bend, south of Marysville, was considered the criterion determining a reliable level of protection (YCWA 2002b). YCWA and the



Source: YCWA 2002b.

Figure 7.1-1. Location of Elements for YFFPP Implementation.

consultants developed 32 program elements, made preliminary estimates of their cost and their contributions to the Shanghai Bend goal, and defined a screening process for selecting the preferred elements (YCWA 2001).

Work was underway on Phase II in October 1999 when the Legislature enacted SB 496, placing the South Yuba River in the California Wild and Scenic River System. This effectively eliminated any measures involving reservoirs on the South Yuba River. Also in October 1999, the Legislature enacted AB 1584, the Costa-Machado Water Act of 2000, subsequently confirmed by the electorate in March 2000 as Proposition 13. The legislation established the YFFPP, which provides grants for flood protection projects on the Yuba and Feather Rivers. These statutes materially affected the YFSFCP.

The screening process now contains consistency checks for the Water Act of 2000 and SB 496. The four-stage process is:

- Financial Feasibility and Level of Protection - Eliminate any elements that cost more than YCWA's estimated financing capacity, or that offer little or no flood protection. YCWA used $240 million as a financing limit, based on an estimated County funding ability of $30 million coupled with assumed 50 percent federal funding and 75 percent State funding of the nonfederal share.
- Consistency with the Water Act of 2000 and SB 496 - Eliminate any elements that would not be fundable under a Water Act of 2000 YFFPP grant (principally those requiring new dams or exceeding the funding ability of the YFFPP) and any that would affect the South Yuba River as a Wild and Scenic River. Consider any new elements that could conform to the YFFPP requirements.
- Public and Agency Scoping - Eliminate any elements that are found impractical considering issues raised during the scoping process and combine elements into YFSFCP alternatives.
- Planning-Level Evaluation - Optimize alternative configurations based on refined estimates of cost and flood protection contributions and technical and environmental considerations (YCWA 2002b).

The quantification of YCWA's goal also changed. In 1999, USACE updated the flood storm characteristics of the Yuba-Feather river system using all available hydrologic data, increasing flood flows for all storm frequencies. As a result, protection from the 500-year flood event, used as an objective in YCWA's *Report on Phase II,* is now seen as protection from approximately a 200-year event. YCWA noted the decrease in level of protection of the identified flood elements, but for Phase II retained the flood control objective of reducing the peak flood volume above 300,000 cfs at Shanghai Bend by 330 taf. That will now provide approximately 200-year protection, or 22% chance of exceedence in 50 years (YCWA 2001; YCWA 2002b).

YCWA completed the draft of the Phase II report in September 2000. The purpose of the Phase II study was to identify and analyze alternatives that could be implemented for supplemental flood protection. From a total of 33 elements evaluated, the draft report identified 11 primary elements for further consideration. The elements were combined into seven alternatives that accomplish 78% to 108% of the flood control objective. The draft report also identified five additional elements for implementation under the YFFPP. Notable conclusions of the report are that there are alternative means of meeting YCWA's flood control objective that warrant further study, that Yuba River flood management must be integrally linked with Feather River flood management to achieve the flood control objective; and that careful maintenance of existing levees is essential to Yuba County flood protection. As of August 2004, the Phase II report remains a draft and YCWA is concentrating on opportunities under the YFFPP.

7.3 STUDY RESULTS

YCWA issued *Report on Phase I, Program Definition* and prepared a draft *Report on Phase II, Formulation and Analyses of Alternatives,* as well as an alternatives analysis report, a scoping report, and several technical memoranda. YCWA has also nearly completed the YFFPP feasibility study, has coordinated the study with the public and governmental agencies, and has identified and refined five of the primary elements of the Project to be implemented under the YFFPP. The five measures were:

- New Bullards Bar Dam Raise - Modify the crest of New Bullards Bar Dam to allow additional flood storage in New Bullards Bar Reservoir. The flood storage capacity could be increased by modifying the existing operation rule curves to allow encroachment into the existing dam freeboard, by structural modifications that raise the dam crest, or by a combination of the two.
- New Bullards Bar Outlet Capacity Increase - Increase releases from New Bullards Bar Reservoir by modifying the existing spillway outlets. About 20,000 cfs or more of additional water could be released if new spillway bays, sluice outlets, or tunnel outlets were constructed. Releasing more water sooner through the modified outlets could produce substantial supplemental flood control benefits.
- New Colgate Powerhouse Tailwater Depression - Use compressed air to depress the tailwater elevation at the powerhouse, allowing turbine operation at high river flows. Currently, the New Colgate Powerhouse begins to lose generation capability when river flows reach 10,000 cfs and must be totally shut down when river flows exceed 25,000 cfs. Curtailing powerhouse flows reduces the rate of release from New Bullards Bar Reservoir. A tailwater depression system would allow the powerhouse to continue to release 3,500 cfs during major storm events, thereby allowing for the evacuation of additional water from the reservoir.
- Forecast Based Operation for Major Storms - Release stored water from New Bullards Bar Reservoir and Lake Oroville in advance of forecasted large inflows to provide additional flood control space. Forecast based operation would be implemented for major storms with reasonably reliable precipitation/runoff forecasts of up to 72 hours. Specific release criteria would incorporate limits on pre-releases to ensure a high probability that released conservation storage would be refilled from storm inflow and not result in loss of water supply or energy production.

- Feather River Levee Setback - Set back the Feather River Levee where the existing channel is most constricted and in a largely rural area, to avoid expensive relocation of infrastructure. Approximately nine miles of setback levees could be constructed on the east bank of the Feather River between the Yuba River and the Bear River. Setback distances could be as much as one-half mile, achieving lower water stages. Downstream hydraulic mitigation, if needed, could be provided by storage in setback areas or operational improvements at New Bullards Bar Reservoir (YCWA 2002b).

The five measures were the result of the Stage 1, 2, and 3 screenings. Two other measures listed in the report have been developed since the draft Phase II report, which includes reoperation of Thermalito Afterbay and enlargement of Lake Oroville instead. Table 7.3-1 lists all of the alternatives considered and contains the results of the three screening stages.

In April 2001, YCWA received a $3,000,000 grant to develop a feasibility study and environmental documentation for the five selected elements of the YFSFCP. In October 2002, YCWA reported separately on one element of the feasibility study, the New Colgate Powerplant tailwater depression project. DWR accepted the report and awarded YCWA a design grant of $510,000, amended in June 2004 to $608,530.

In September 2003, the original feasibility study, now without the New Colgate element, was amended to include more detailed studies of the setback levee on the Feather River, and the grant was increased to $3,785,000. The grant was again increased in June 2004 to $4,143,700 to cover new studies of levee setbacks on the Bear River and the Western Pacific Interceptor Canal, made necessary by concerns about freeboard and levee stability.

Funding for design and implementation is expected to be available for the resulting flood protection measures (pers. comm., Yamanaka, 2003).

YCWA is conducting the YFFPP feasibility study under a contract with DWR that requires a work plan detailing the study tasks and quarterly progress reports describing the quarter's work performed and costs incurred and containing a schedule comparing actual progress to the planned schedule. Payment is made only for completed work and depends on submittal of satisfactory progress reports. The study was initiated on March 1, 2001 and now has a completion date of March 15, 2005. YCWA is current with its quarterly reports and it appears that the study will be completed on time (pers. comm., Yamanaka, 2003). For the feasibility study, YCWA has produced the following (pers. comm., Hinojosa, 2004):

- Final feasibility study report, to be supplemented by a separate report on the levee setbacks, and including under separate cover the appendices listed immediately below
- Appendix A - Hydrology
- Appendix B - Operation Studies

- Appendix C - Configuration and Optimization of Elements
- Appendix D - Benefit Analysis
- Appendix E - Preliminary Design

Table 7.3-1. Elements of YCWA Yuba-Feather Supplemental Flood Control Project.

Added Before Stage	Number	Element	Eliminated in Stage							Retained for Stage 4	Comments	Page in Reference (Sec. VI)
			1		2			3				
			Too Costly	Little Protection	Too Costly	New Dam Involved	South Yuba Storage	Out of Scope	OK but By Others			
1	2	Watershed management		x							No significant help to flood protection	1
1	3	Increase flood storage, no outlet work at Oroville	x								Cost to restore water supply is prohibitive	3
1	4	Increase flood storage, no outlet work at NBB		x							Ineffective due to limited outlet capacity	4
1	6	Increase flood storage, enlarge outlet at Oroville	x								Impractical to finance, cuts water supply	4
1	7	Increase flood storage, enlarge outlet at Englebright	x	x							High cost, limited flood protection	4
1	9	Increase flood storage, enlarge outlets at Yuba headwaters	x	x							High cost, limited flood protection	4
1	10	Floodproofing	x								High cost, limited infrastructure protection	5
1	11	Facilities relocation	x								High cost, not practical	5
1	12	Reservoir enlargement at Englebright	x								High cost, limited flood protection	5
1	16	Detention basin in RD 784	x								High cost, limited flood protection	5
1	18	Detention basin at Edwards Crossing	x								Multipurpose reservoir has better benefits	6
1	19	Small detention basins at several locations	x								High cost, limited flood protection	6
1	20	Flood control reservoir at Parks Bar	x								Multipurpose reservoir has better benefits	6
1	21	Flood control reservoir at Edwards Crossing	x								Multipurpose reservoir has better benefits	7
1	28	Transbasin diversion at Lake Spaulding	x								High cost, limited flood protection	12
1	29	Flood bypass via Reeds Creek, WO Interceptor, Bear R	x								High cost	7
1	30	Raise levees	x								High cost, uncertain reliability, impacts	7
1	31	Levee setback	x								High cost, impacts, but partly kept as #36	8
1	32	Channel dredging	x								Ineffective, levee damage, high cost	9

Source: YCWA 2002b.

Table 7.3-1. cont'd. Elements of YCWA Yuba-Feather Supplemental Flood Control Project.

Added Before Stage	Number	Element	Eliminated in Stage							Retained for Stage 4	Comments	Page in Reference (Sec. VI)
			1		2			3				
			Too Costly	Little Protection	Too Costly	New Dam Involved	South Yuba Storage	Out of Scope	OK but By Others			
1	8	Increase flood storage, enlarge outlet at NBB			x						Exceeds WA2000 available funds	12
1	15	Enlarge Thermalito Afterbay			x						Exceeds WA2000 available funds	12
1	17	Detention basin at Parks Bar			x	x					Exceeds WA2000 available funds and scope	12
1	22	Multipurpose reservoir at Freemans Crossing				x					Exceeds WA2000 scope	12
1	23	Multipurpose reservoir at Edwards Crossing				x	x				> WA2000 scope; barred on W&S river	12
1	24	Multipurpose reservoirs at Lower Narrows			x	x	x				> WA2000 funds, scope; barred on W&S river	12
1	25	Multipurpose reservoirs at Parks Bar & French Dry Creek			x	x					Exceeds WA2000 available funds and scope	12
1	26	Offline conservation reservoir at Waldo on Dry Creek			x	x					Exceeds WA2000 available funds and scope	12
1	27	Offline conservation reservoir at French Dry Creek			x	x					Exceeds WA2000 available funds and scope	12
1	1	Flood Warning							x		Already done by Yuba County	14
1	14	Reservoir enlargement at Oroville						x			No benefits > #37; impacts on SWP, OWID	15
1	5	Reoperate Thermalito							x		Recommended DWR do with operations	16
3	37	Lake Oroville surcharge							x		Recommended DWR do with operations	16
1	13	Reservoir enlargement at New Bullards Bar								x		
2	33	Outlet enlargement at New Bullards Bar								x		
2	34	New Colgate tailwater depression								x		
2	35	Forecast-based operations								x		
3	36	Feather River levee setback								x		

Source: YCWA 2002b.

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- Appendix F - Capital and O&M Costs
- Appendix G - Forecast-Coordinated Operations
- EIR, project level for all elements except the levee setbacks, which are at programmatic level
- Draft supplemental feasibility study report for levee setbacks, which will include Appendices I through VI.
- Draft Appendix I - Hydrology
- Draft Appendix IV - Benefit Analysis
- Administrative Draft EIR covering the levee setbacks at the project level

The New Colgate Powerhouse tailwater depression project has been carried forward independently because it would have minimal environmental impacts, would be cost-effective as a stand-alone element, and could be implemented quickly. This element has been evaluated environmentally in a separate California Environmental Quality Act document (YCWA 2002b). YCWA completed the feasibility study for New Colgate in October 2004 and is now designing the project under a DWR contract that includes controls on planning, reporting, and payment that are similar to the feasibility study contract. Design was initiated in June 2003 and had a completion date of October 2004. YCWA is current with its quarterly reports and it appears that the study will be completed on time (pers. comm., Yamanaka, 2004).

7.4 ANALYSES

YCWA has established the need for additional flood protection in the Yuba-Feather area and is conducting a well-structured campaign to define, plan, finance, and implement appropriate measures to obtain it. Having defined a program to identify and implement means to accomplish a quantified objective of volume reduction at Shanghai Bend, they have adapted to emerging funding opportunities and are pursuing YFFPP funds to meet part of the quantified goal. This shift in emphasis is consistent with their goal statement that calls for implementing flood control actions as soon as possible. YCWA acknowledges that elements eligible for funding under the YFFPP will provide only about half of the Shanghai Bend peak volume reduction goal of 330,000 acre feet and that the goal itself must be revised to conform to the new USACE hydrology. The *Report on Phase II* notes that “Additional elements . . . should be further evaluated in Phase III work, Planning for Implementation of Primary Alternatives, following initiation of . . . projects under the Water Act of 2000.” (YCWA 2001) Phase III and the remainder of the program remain active issues to be pursued when the YFFPP work is completed.

8.0 SACRAMENTO AND SAN JOAQUIN RIVER BASINS COMPREHENSIVE STUDY

8.1 INTRODUCTION

This report describes the Sacramento and San Joaquin River Basins Comprehensive Study. The Reclamation Board of the State of California and USACE are preparing the Study. The report covers the Study's organization, study approach, findings, and output products.

The purpose of this report is to contribute to the investigation of Feather River flood control as a part of the project to relicense the Oroville Facilities. The report contains background information, descriptions of the Study's seven regions, a description of the Study, and an analysis of its principal results. There are two embedded figures. There are no tables.

8.1.1 Background Information

California's 43,000-square-mile Sacramento and San Joaquin River Basins cover most of California's Central Valley and are home to more than four million people and a wide variety of fish, wildlife, and plants. The river basins provide water to most Californians and crops to the nation and the world. Flood risk in this region is rising, as are conflicts between flood maintenance, growing population, agricultural interests, and ecosystem needs.

The rivers historically meandered across the valley, eroding and depositing sediments and creating diverse habitat. During high water, the rivers overflowed into large low-lying basins or adjacent floodplains. This flooding reduced peak flow rates, replenished groundwater, and supported wetland communities.

The 1849 California Gold Rush brought thousands of people to the Central Valley. Riparian trees became steamship fuel. Soon after 1850, settlers cleared forests and filled oxbow lakes and sloughs to plant crops. They built levees to address local flooding, considering neither the wider hydraulic impact nor the natural river processes. Hydraulic mining blocked Sacramento River tributaries with sediment. Large storms during the 1850s and 1860s caused widespread levee failures.

In the early 1900s, government began to develop systems of levees, weirs, and bypasses to increase conveyance, aid navigation, and flush sediment. The systems significantly reduced meandering and isolated the rivers from their floodplains. Local improvements often increased flood risk in other areas. Dams significantly reduced peak flow magnitudes but also increased the duration of high flows and the chance of levee failure due to erosion and saturation (USACE 2002b).

8.1.1.1 Statutory/Regulatory Requirements

Since the 1970s, there has been increased environmental awareness, reflected in new laws such as the National Environmental Policy Act, the California Environmental Quality Act, and the Federal and State Endangered Species Acts and in new programs. In 1995, eighteen federal and State agencies formed the CALFED Bay-Delta Program to develop a plan to restore ecological health and improve water management in the San Francisco Bay-Sacramento/San Joaquin Delta system.

In 1997, the California Governor's Flood Emergency Action Team (FEAT) called for comprehensive evaluation of Valley flood control systems, to result in a programmatic master plan to improve flood protection and restore or enhance the environment (FEAT 1997). The State Legislature in 1997 and Congress in 1998 authorized the Sacramento and San Joaquin River Basins Comprehensive Study, to be carried out by The Reclamation Board and USACE. The Study produced the Comprehensive Plan, a process for developing projects to meet public safety, flood damage reduction and ecosystem restoration objectives (USACE 2002b).

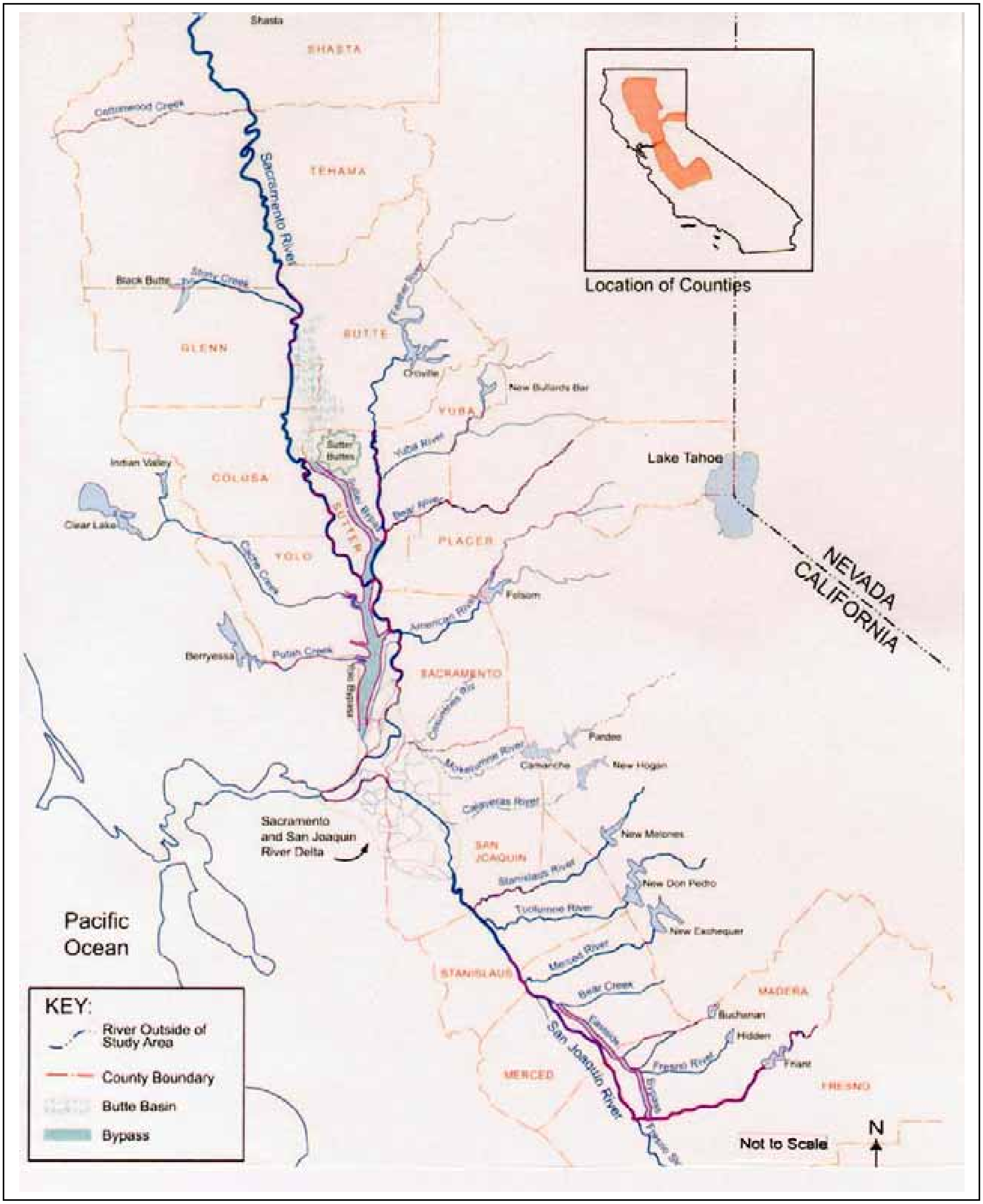
8.1.1.2 Study Area

The Comprehensive Study focuses on solving flooding and ecosystem problems within the floodplains of the Sacramento River, the San Joaquin River, and their major tributaries. The Comprehensive Study area is contained in the CALFED study area. The Tulare Lake Basin is not included, but flood flows from the Kings River to the San Joaquin River are considered. The Cosumnes, Mokelumne, Calaveras, and American Rivers, Cache Creek, and other streams are the subject of separate studies, but impacts of these streams are considered in the technical studies. Figure 8.1-1 shows the Study area and identifies the rivers and principal tributaries. The Study area is subdivided into seven regions, shown in Figure 8.1-2 (USACE 2002b).

Feather River Region

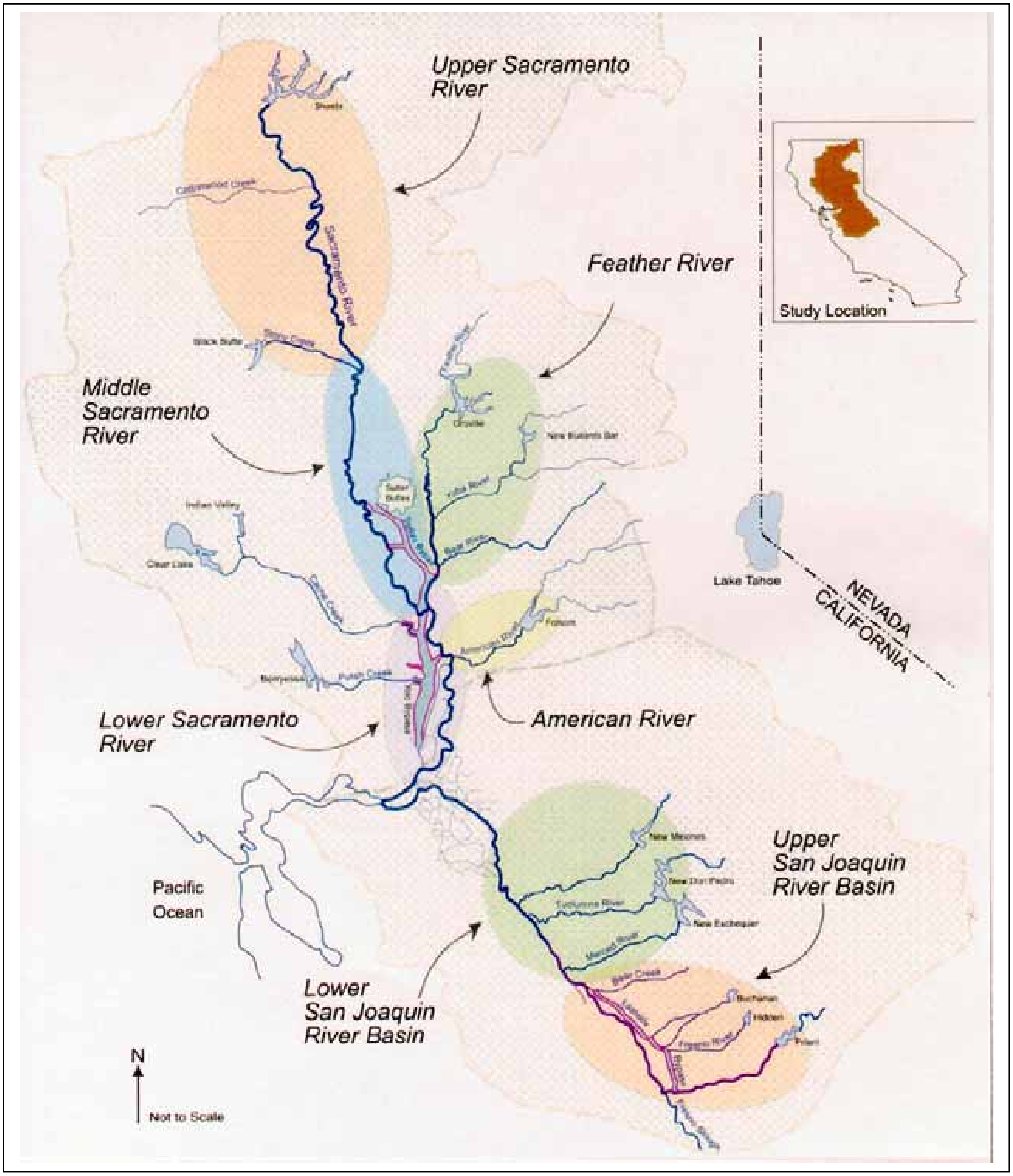
The Feather River region includes the Feather, Yuba, and Bear Rivers, their tributaries from their headwaters to the Fremont weir, Lake Oroville on the Feather River, and New Bullards Bar Reservoir on the Yuba River. Agriculture is prevalent between the wide-set levees of the region's rivers. There has been significant urbanization throughout the region in the last decade. An estimated 125 special-status species can potentially occur in the region.

The Feather River can flow at more than 300,000 cfs at Marysville. Upstream, Oroville Dam impounds more than 3,500 taf. Deposition of mining sediments transformed the Feather River into a wide and shallow channel with sandbars and low sinuosity. The lower Feather River experiences deposition caused by backwater from the Sacramento River and flow area expansion at the confluence. The Feather River Wildlife Area is



Source: USACE 2002b.

Figure 8.1-1. Comprehensive Study area and principal streams.



Source: USACE 2002b.

Figure 8.1-2. Comprehensive Study regions.

situated along the lower Feather River floodway. The Feather River Fish Hatchery below Oroville Dam recovers anadromous fish that migrate up the river. The Middle Fork, above Lake Oroville, is part of the California Wild and Scenic River System.

The lower Yuba River has high terraces of mining sediment alongside a degrading river channel with a steep gradient. New Bullards Bar Dam impounds nearly a million acre-feet but intercepts less than 40 percent of the Yuba River runoff. The Yuba provides valuable spawning and rearing habitat for shad, striped bass, salmon, sturgeon, and steelhead. The South Yuba River, a tributary above New Bullards Bar Reservoir, is part of the California Wild and Scenic River System.

The Bear River exhibits low sinuosity and channel degradation over the last century. Habitat conditions in the lower Bear River are generally not favorable for trout or anadromous fish. Spawning is severely limited by silted spawning gravels and high water temperatures (USACE 2002b).

Upper Sacramento River Region

Shasta Dam and Chico Landing, separated by a distance of about 118 river miles, bound the Upper Sacramento Region. From Shasta Dam to Red Bluff the river is constrained by erosion-resistant volcanic and sedimentary formations. From Red Bluff to Chico Landing, the river historically meandered across the broad Sacramento Valley alluvial floodplain. Eighteen unregulated tributaries enter the system and as a group can contribute significant flows. There are SRFCP levees on Elder Creek and Deer Creek but the river has no SRFCP levees in this region. Local levees exist in various locations. Twenty miles of bank protection has been placed along the river by the federal government.

Objective releases are 79,000 cfs at Keswick Dam and 100,000 cfs near Red Bluff. Uncontrolled tributaries can increase this to well above the 100,000 cfs channel capacity. Damage can occur at a flow as low as 15,000 cfs depending on the season. Shasta Dam operation, bank protection and levees, and gravel mining have disrupted physical processes. These actions have contributed to loss of fish and wildlife habitat. The Sacramento River Conservation Area Forum has worked since 1986 to develop a management plan to improve fisheries and riparian habitat in the Region (USACE 2002b).

Middle Sacramento River Region

The Middle Sacramento River region extends from Chico Landing in the north to Fremont weir in the south, about 111 miles. Stony Creek, regulated by Black Butte Reservoir, and the Big Chico Creek system, with SRFCP levees, enter just below Chico Landing. On the river, the west SRFCP levee begins at Ord Ferry Road and continues to the Delta. On the east side, flood flows enter Butte Basin through several overflow areas at natural low points. The SRFCP levee begins near Butte City and continues to the Delta. Moulton weir and Colusa weir divert flood flows into Butte Basin. The Sutter Bypass begins about 56 miles downstream of Chico Landing where Butte Basin flows enter it and rejoins the Sacramento River at Fremont weir. The Tisdale weir allows flood flows from the river to the Sutter Bypass. The Bypass perpetuates the flow pattern through Sutter Basin, but levees modify the pattern to protect reclaimed lands. Levees separate the river and Colusa Basin, west of the river. The basin’s runoff is diverted either to the river or to the Yolo Bypass via the Knights Landing Ridge Cut. Levees are generally set back from the river for 50 miles from Chico Landing to Colusa. From there to Fremont weir, the levees are set close to the river. In many places, the levee is built of substandard materials and on poor foundation. Erosion degrades the channel and undercuts levees and rock bank protection. In response, USACE has placed miles of bank protection.

The levee/bypass system, dam construction, and bank protection have adversely affected the ecosystem, reducing shaded riverine aquatic habitat. Separation of the Colusa Basin, channelization of the Sutter Basin, and flow management in the Butte Basin have modified the flows in this region, causing loss of habitat and resulting in less diversity and productivity (USACE 2002b).

American River Region

The American River region contributes significant flows to the Lower Sacramento River Region. Folsom Lake has a capacity of 977 taf with a 400 taf flood reservation. Fifty-four additional reservoirs provide hydroelectric generation and water supply but have no flood reservation. From Folsom Lake, the American River flows through Sacramento to the Sacramento River (USACE 2002b).

Lower Sacramento River Region

The Lower Sacramento River region extends from Fremont weir to the Delta. It contains the Sacramento metropolitan area. Historic overflow areas for lower Sacramento River floodwaters are the American Basin to the east, now separated by levees, and the Yolo Basin to the west, largely the same as the Yolo Bypass. The lower Sacramento River is perched above the surrounding terrain, with moderate sinuosity and a low gradient decreasing downstream. The region includes the Yolo Bypass, Fremont weir, Sacramento weir and Bypass, and lower reaches of tributary streams. The Feather River, the Sutter Bypass, and the American River are major tributaries. The Yolo Bypass leaves the Sacramento River westerly at Fremont weir and re-enters the river at Rio Vista. Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek are primary sources of inflow to the Yolo Bypass. The region’s only flood control reservoir is Indian Valley Reservoir on the north fork of Cache Creek, but conditions in the region are critically influenced by reservoir operations at Folsom, Oroville, New Bullards Bar, and Shasta. River levees are mostly constructed of river sand and clay. Seepage is a primary concern. The river surface during flood events is higher than the surrounding area, causing a risk of deep and rapid flooding. Yolo Bypass levees are constructed of adjacent material. The bypass is up to 5 miles wide and levee erosion from wind-driven waves is a critical problem. Sediment carried from upstream and from tributaries is deposited mainly in the bypass and the Delta. The Fremont weir and the Sacramento weir are key components of the SRFCP, distributing flood flows to the river and the Yolo Bypass. Flows of more than 600,000 cfs have passed through the region and proper division of flow is critical to the safety of the Sacramento urban area. At high stages, the river raises water surfaces in the Delta and tributaries.

Riparian forests along the river have been reduced to narrow remnants. In the 59,000-acre Yolo Bypass, wetlands have been reduced in size and have become highly managed areas. Riparian growth occurs mainly in narrow strips along irrigation canals and tributaries except for a few larger areas. Numbers of migratory fish have been greatly reduced due to barriers on the tributaries. The Yolo Bypass attracts migratory fish, particularly in high water, but migration over the Fremont weir is only possible infrequently when the weir is spilling. Dam and SRFCP construction, flood maintenance, and urban and agricultural development have caused a sharp decline in the quantity, diversity, and viability of natural riverine and floodplain habitats and species (USACE 2002b).

Upper and Lower San Joaquin River Regions

The Upper and Lower San Joaquin River regions include the San Joaquin River from Friant Dam to Stockton, five major and several minor tributaries, and distributaries in the Delta. The flood management system includes flood storage behind six multipurpose and several dry dams, a federal bypass system from Gravelly Ford to downstream of the Merced River, intermittent and continuous federal levees from the Merced River to the Delta, and many miles of local levees around Delta islands.

In large events on the Kings River, additional flows enter below Gravelly Ford. Discharges often exceed the bypass system’s design capacity, leading to frequent levee failures. Significant seepage also occurs. Differential subsidence has diminished bypass capacity. Urban development has created pressure for building on Delta island overflow areas. During floods, the river often ponds in the south Delta.

Water resource development has reduced the water available for natural processes, contributing to declining plant, fish, and wildlife populations. Diversion for water supply has eliminated aquatic habitat along much of the river, excepting remnants above Gravelly Ford. Water is now generally unavailable to support ecosystems on the river. Past farming practices directed sediment to fill lower areas for farming. Irrigation return flows have also directed sediment toward the river. Upstream diversions have reduced flushing flows (USACE 2002b).

8.2 METHODOLOGY

8.2.1 Study Design

During the first two years, the Comprehensive Study focused on collecting information on system-wide problems. The third-year focus was on verifying the baseline conditions. The fourth year focused on evaluating system response to modifications. In the last year, the Study focused on developing the Comprehensive Plan (USACE 2002b).

8.2.2 How and Where the Studies Were Conducted

The Reclamation Board and USACE, Sacramento District, are preparing the Comprehensive Study. Both agencies are in Sacramento, California. The study is using input from many agencies, organizations, and individuals throughout the Central Valley.

Throughout, public and agency participation mirrored the progress of the study. To reach a representative sample of people, the Study established technical and local support groups composed of federal, State, and local experts. These groups helped identify potential solutions to problems. The Study also developed a set of system-wide hydrology and hydraulic models. Representative professionals in the water field provided input on the models.

The Study held 22 general public workshops and forums in nine cities to exchange information. Study team members provided updates at many public hearings, agency meetings, technical conferences, and other forums. Study team members also provided updates to public officials and other audiences upon request. The Study established a policy focus group to identify issues and institutional barriers that affect implementation of flood damage reduction, associated land use planning, and environmental restoration.

The Study developed and employed computer models to examine potential projects and track their effects on the entire system. To support the effort, the Study obtained recent surveys and mapping, including topographic contour mapping, digital elevation models, and aerial photographs (USACE 2002b).

8.3 STUDY RESULTS

The Comprehensive Study stated these important overall findings:

- There are locations where the flood control system cannot carry design flows.
- To avoid downstream impacts, upstream storage increases must accompany levee improvements.

- A comprehensive solution to flooding problems will include better levees, more storage, and better floodplain management.

A primary output of the Study is the Comprehensive Plan, a process for developing future projects on system-wide, regional, and local bases, under ten guiding principles. The development process and the guiding principles are discussed at greater length in Section 8.4 below. Following up the issuance of the Comprehensive plan, projects have been begun that will apply the Plan’s principles. The Hamilton City Flood Damage Reduction and Ecosystem Restoration is in the feasibility study stage and is discussed in Section 8.3.3.1 (USACE 2003b). The Enhanced Flood Response and Emergency Preparedness (EFREP) project will culminate in a plan formulation/environmental documentation report (USACE 2002c). It is the subject of Section 8.3.3.2.

8.3.1. Findings in the Regions

8.3.1.1. Feather River Region

The Study found that the wide levee spacing in the Feather River region offers opportunities for flood management and ecosystem improvements. These opportunities include widening constricted areas, restoring ecosystems by providing seasonal inundation, managing agricultural lands more compatibly with fish and wildlife habitat, implementing forecast-based reservoir operations, increasing effective flood storage using upstream reservoirs, modifying reservoir releases for a more natural hydrology, addressing water temperature needs for anadromous fish, and improving stream connectivity for fish migration and public access to streams for recreation. Many of these opportunities would address CALFED goals and those of the Anadromous Fish Restoration Program (USACE 2002b).

8.3.1.2. Upper Sacramento River Region

The Study found opportunities to improve flood management and restore the ecosystem by re-operating upstream reservoirs, increasing storage in Lake Shasta and redesigning reservoir operations, and using off-stream storage. There are opportunities to work with conservation easements and to develop agriculture/ecosystem partnerships (USACE 2002b).

8.3.1.3. Middle Sacramento River Region

The Study found significant ecosystem restoration potential where the levees are wide-set. It also found opportunities for agriculture/ecology partnerships, for purchasing conservation easements in cooperation with growers, and for reducing constrictions, restoring the ecosystem, and improving the levees by widening selected reaches (USACE 2002b).

8.3.1.4. *American River Region*

Because this region is already the subject of intense study and is well documented in other reports, the Comprehensive Study only analyzes conditions that affect the other regions (USACE 2002b).

8.3.1.5. *Lower Sacramento River Region*

Limited capacity to handle flood flows is a major consideration in planning projects in this region that include ecosystem restoration. Projects with environmental features that increase flood stages must be balanced with stage-reducing hydraulic features. The river has limited opportunity for ecosystem restoration, but there are significant opportunities in the Yolo Bypass. The Study has identified opportunities to reduce flood damage, increase riparian vegetation, and provide flood benefits to adjacent lands by increasing the flood flow in the Yolo Bypass. The unique tidal and other characteristics of the Bypass present a rare opportunity to restore habitats, connect wildlife areas, improve fish migration, and enhance the ecosystem, all consistent with the CALFED goal of managing the Yolo Bypass as an area of seasonal shallow water (USACE 2002b).

8.3.1.6. *Upper and Lower San Joaquin River Regions*

The Study has identified four opportunities. They are improving flood protection and restoring more natural hydrology by modifying reservoir operations; providing ecological and flood benefits by increasing water supply; realigning Delta levees to create better flood protection and restore riparian habitat, and using conservation lands to create overbank flooding and flood attenuation by removing levees and constructing control weirs (USACE 2002b).

8.3.2 Computer Models

The Comprehensive Study produced, adapted, collected, and organized extensive data and tools of analysis in the process of synthesizing an approach to future project development. These include a database of surveys, mapping, and hydrologic data and computer models for examining the effect of potential projects on the entire river system.

The collection of topographic data covers reaches that include the main river channel, levees (if present), and the overbank areas for a distance of approximately 300 feet landward of the levees. Black and white aerial photographs were also obtained along the river corridors. Topographic data were collected using hydrographic, photogrammetric, and LIDAR techniques. Bathymetric data provided detailed channel geometry below the waterline. In the overbank areas, U.S. Geologic Survey 30-meter and 10-meter digital elevation models were used to develop the hydraulic model input.

Current mapping in the Sacramento River Basin was readily available. The Sacramento data were collected between 1995 and 1999 and consist of two-foot contour mapping above and below the waterline along the major watercourses, with some exceptions. Due to the absence of current mapping, topographic data were collected in the San Joaquin River Basin specifically for the Study. Hydrographic and photogrammetric surveys were conducted in 1998 and an overbank area survey in 2000. Data produced two-foot contour mapping above and below the waterline along the major watercourses.

Hydrologic data consist of flows and volumes observed in historic floods and historic storm patterns observed across California, obtained largely from the California Data Exchange Center and the NWS.

The Study developed system-wide evaluation models to better understand the complex hydrologic, hydraulic, economic, and ecologic processes that interact in the Central Valley’s rivers and floodplains. Before the Study, no models existed that evaluated Central Valley river systems on a watershed scale. The models encompass the entire river system, from the upper watersheds to the Delta. They provide capability to evaluate the operation of the existing system and to analyze future projects.

Models were developed in the seven technical areas of surveys and mapping, hydrology, geotechnical analysis, hydraulics, flood damage analysis, ecosystem functions, and information management. The whole forms an interconnected suite for evaluating the effects of project variables on the water flow, riverine processes, and ecology of the river system. (USACE 2002b).

8.3.2.1. Surveys and Mapping Models

Surveys and mapping models are the result of organizing the data collection. They include the collected data described above, expressed in digital format for use in a computer-assisted design or geographic information system format (USACE 2002b).

8.3.2.2. Hydrology Models

Hydrology models are for synthetic hydrology and reservoir operation. Synthetic, unregulated 30-day hydrographs were developed for seven flood events: those with a 50%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance of occurring in any year. The Study created more than 13,000 unregulated hydrographs at more than 50 locations. Historic storm patterns across California provided 27 different storm centerings to simulate floods involving multiple tributaries and reflect the influence of the coastal and Sierra Nevada mountain ranges.

The Study used the USACE HEC-5 computer program to develop two separate reservoir operations models in each basin, one for the smaller but more numerous headwater reservoirs and another for the larger foothill reservoirs. Together, the models simulate 44 headwater reservoirs and 28 foothill reservoirs tributary to the San Joaquin River, while the Sacramento models simulate 27 headwater reservoirs. The models use mandatory flood operations where established, or operational criteria provided by facility operators or obtained by analyzing gage data. The unregulated hydrographs are input to the headwater reservoir models. Results from the headwater reservoirs are input to the foothill reservoir models. The end result is regulated flood flows downstream from the foothill reservoirs (USACE 2002b).

8.3.2.3. Geotechnical Analysis

Geotechnical analysis was performed to determine the stability and reliability of the levees. A model of levee failure was developed that simulated levee reliability by establishing a likely failure point (LFP) profile along both riverbanks, as the stage at which probability of levee failure is 50%. Levee failure curves were determined reach by reach based on available soil type and levee geometry, interviews with levee district personnel, levee performance, and engineering judgment. They were then used to establish the LFP for each location. The LFP reflects a worst-case condition without flood fighting or other emergency actions (USACE 2002b).

8.3.2.4. Hydraulics Models

Hydraulics models simulate river and floodplain hydraulics and flood conditions in the Delta. River hydraulics is simulated using UNET, a computer program that simulates unsteady flow. The Study developed separate UNET models for the Sacramento and the San Joaquin River systems, from the major flood control reservoirs to the Delta. Channel cross sections are spaced approximately one-fourth mile. The regulated hydrology from the reservoir operation models is input for the river hydraulics models. These simulate levee failures, storage in adjacent basins, weirs and overflow structures, and bridges. The models represent vegetation and channel obstructions by varying roughness coefficients. Levee failure occurs at the elevation of the LFP. The models do not simulate emergency flood fighting, sediment movement, scour, deposition, ground water exchange, or water temperature. The models were calibrated to the 1995 and 1997 floods. Output is flow, stage, velocity, and other hydraulic parameters at every cross section.

The floodplain hydraulics models use the FLO-2D program to simulate flow across floodplains. Out-of-bank flows from the river hydraulics models are input to the floodplain hydraulics models. Topography is represented as a two-dimensional square grid about 2,000 feet on the edge. The models calculate water depth and estimate the extent of flooding. Inundation areas from multiple storm centerings are used to delineate a single composite floodplain.

The study team adapted DWR's DSM2 program to simulate Delta flows and stages. The team re-calibrated the model to simulate floods and truncated it so that input locations coincide with the locations of the output of river hydraulics models. Delta simulation input includes inflows from the river hydraulics models and flood flows from other Delta tributaries. Output includes stage, flow, and storage volume data. The model does not simulate levee failure or the effect of extended high stages on levee stability (USACE 2002b).

8.3.2.5. Flood Damage Analysis Modeling

Flood damage analysis modeling uses the USACE HEC-FDA computer program to estimate economic damages and quantify the risk of flooding. The flood damage models use stage and discharge data from the river hydraulics models and composite floodplain data from the floodplain hydraulics models, along with geotechnical data and information on land use, property value, and flood depth/damage relationships. The models calculate expected annual damages that could be caused by a full range of possible flood events, then use that result to calculate flood risk in three ways:

- Annual exceedence probability**,** the likelihood that an area will be flooded in any given year, accumulates all uncertainties into a single risk value.
- Long term risk**,** the probability that damages will occur during a specified timeframe, is reported for 10-year, 25-year, and 50-year periods.
- Conditional nonexceedence probability, the probability of safely containing a flood with a known frequency, is reported for the 10%, 4%, 2%, 1%, 0.5%, and 0.2% floods.

Floodplains were divided into 110 smaller impact areas, based primarily upon sources and flow patterns of floods and the underlying land uses. The outermost extent of the impact areas is based upon the 0.2% floodplain (USACE 2002b).

8.3.2.6. Ecosystems Functions Model

The ecosystem functions model consists of a series of analyses that are used to evaluate existing and project conditions that favor various types of habitat. It is applied reach-by-reach in five major steps:

- Step one, ecological analysis, identifies biological relationships between flow duration, flow frequency, and stage recession and the aquatic and terrestrial ecosystems.
- Step two, hydrologic analysis, statistically uses daily flow and stage records and the results of step one to calculate flows for specified durations, flow frequencies, and stage recession rates under historical, existing, and project conditions.
- Step three, hydraulic analysis, simulates the hydraulic response of the river system to the stream flows estimated in step two using the USACE HEC-RAS program to obtain simulated stages and flood inundation areas. Results are expressed in geographic information system format.

- Step four, graphical presentation, uses a geographic information system (GIS) computer program to display the results and other geographic information, enabling a spatial evaluation of the biological relationships.
- Step five, ecological interpretation, done manually using the modeled changes in habitat and environmental and landform features, provides conclusions and recommendations on the impacts of projects (USACE 2002b).

8.3.2.7. Information Management

Information management represents the input and results of the modeling in a GIS database (USACE 2002b).

8.3.3 Projects

8.3.3.1. Hamilton City Project

In March 2004, USACE produced a draft feasibility study and EIR/EIS for the Hamilton City Flood Damage Reduction and Ecosystem Restoration. In the study USACE developed and evaluated alternative plans to reduce flood damages and restore the ecosystem along the Sacramento River at Hamilton City, about 85 miles north of Sacramento.

Hamilton City is a community of about 2,000 people in an area of primarily fruit and nut orchards. A local levee constructed in 1904 provides a degree of protection to the community and surrounding lands, but it was constructed mostly of silty sand and is subject to frequent flood fight emergencies, including a failure in 1974. Construction of the levee altered native habitat and natural river function, constraining the ability of the river to meander and promote favorable conditions for native vegetation.

The feasibility study report tentatively recommends a plan including 5.2 miles of setback levee along the west side of the Sacramento River, beginning about two miles north of Hamilton City and proceeding downstream. At Glenn County Road 23, about 3.6 miles southeast of Hamilton City, the levee becomes a training dike and extends and additional 1.6 miles. The project would restore the ecosystem on 1,480 acres, producing 1,000 acres containing local riparian species, 260 acres of scrub, 150 acres of oak savannah, and 70 acres of grassland. The project cost is estimated at about $45 million. It has a benefit/cost ratio for flood damage reduction of 1.8.

The Reclamation Board certified the EIR/EIS as lead agency under CEQA and approved the project. The feasibility study report is now under further federal review pending final USACE approval and Congressional authorization of the project (USACE 2004a).

8.3.3.2. *Enhanced Flood Response and Emergency Preparedness Project*

The system-wide EFREP study is also a Comprehensive Study project. The FEAT report of 1997 recommended 15 improvements to emergency response. In performing the EFREP study, the Comprehensive Study team evaluated the FEAT recommendations, developed a set of enhancements to the existing flood response and emergency preparedness system, and produced a preliminary draft feasibility report/environmental assessment/initial study. The report summarizes data on existing and future conditions, discusses flood warning system problems and opportunities, describes and compares developed alternatives, evaluates the potential environmental effects of the alternatives, discusses mitigation measures and performance standards, discusses compliance with applicable laws. It includes a tentative recommended plan.

The draft report currently describes three alternatives. The alternatives are additive, beginning with a minimum effort and incorporating lesser alternatives in each succeeding larger plan. The minimum plan contains notification and decision-making measures. The moderate plan would add measures for enhanced detection. The maximum plan also contains data collection and data management enhancements.

The tentatively recommended plan is the moderate plan. Features of the plan are:

- Enhanced exchange and reporting of reservoir data, accomplished by partnering with operators of 25 reservoirs to integrate existing forecasts into flood simulations, expand Flood Center information on reservoir operations, and implement automated exchange of inflow forecasts and release schedules
- An additional data receiver site
- 20 handheld computers for field use in event visualization
- Flood Center acquisition of Comprehensive Study products and equipment for using them, including a GIS workstation and color plotter
- Development of more user-friendly forecast language
- 80 additional staff gages at critical points
- Classes for local emergency personnel on flood response and decision making
- Better public notification
- Public awareness programs in partnership with news media
- 14 videoconferencing facilities for area operations centers
- 20 digital cameras and equipment to transmit field pictures to the Flood Center
- Expansion of the Response Information Management System and the Flood Operations Center Information System
- Hydrology training for emergency responders
- Updates of Standardized Emergency Management System assignment and responsibility descriptions
- Completion of 14 county flood response plans
- Enhancement of vulnerability analysis capability in 14 counties.

The estimated first cost of the tentatively recommended plan is $10.3 million. It would have estimated net annual benefits of $3.7 million and a benefit-cost ratio of 2.5. Annual flood damage reduction is estimated at $6.1 million, 6.5 percent of the estimated annual damages, and annual cost of maintenance, operations, replacement, and interest is estimated at $2.4 million. The plan would increase flood warning (mitigation) time an estimated 0 to 31 hours, depending on the locations of the area to be protected and the source of the flooding.

8.4 ANALYSES

The Comprehensive Study's charge was expressed in the 1997 FEAT call for comprehensive evaluation of flood control systems in the Central Valley. The resulting Comprehensive Plan is a process, founded in system-wide evaluation of project impacts, for developing future projects to meet the system's comprehensive public safety, flood damage reduction, and ecosystem restoration objectives. This process consists of a set of principles to guide future projects, an approach to developing projects with consideration for system wide effects; and an administrative structure to consistently apply the guiding principles.

A major undertaking of the Study was developing the analytical tools to evaluate the effects of changes to the system. During the course of the Study, the existing system and representative projects were evaluated to understand how the system functions and responds to changes. The evaluations led to these important findings about the flood management system: The system cannot safely convey the flows that it is rated to carry. If levees were improved system-wide, substantial increases in storage would be necessary to avoid transferring flood risks downstream. A comprehensive solution to improve flood protection and restore ecosystems will require increasing conveyance capacity, increasing flood storage, and improving floodplain management (USACE 2002b).

8.4.1 Guiding Principles

The Study identified guiding principles to ensure that projects integrate flood damage reduction and ecosystem restoration and consider system-wide implications. They are:

- Recognize that public safety is the primary purpose of the flood management system.
- Promote effective floodplain management.
- Promote agriculture and open space protection.
- Avoid hydraulic and hydrologic impacts.
- Plan system conveyance capacity that is compatible with all intended uses.
- Provide for sediment continuity.
- Use an ecosystem approach to restore and sustain the health, productivity, and diversity of the floodplain corridors.
- Optimize use of existing facilities.

- Integrate with CALFED and other programs.
- Promote multi-purpose projects to improve flood management and ecosystem restoration (USACE 2002b).

8.4.2 Approach To Developing Projects

Projects will be developed on system-wide, regional, and local scales. Regardless of its scale, each project must be evaluated to determine the system-wide effects. Public needs and expectations define the scope of projects.

- System-wide projects could be pursued with broad public support and could yield more total benefit for less individual cost than limited projects. However, system-wide projects are likely to be primarily nonstructural in nature because public needs and expectations are so diverse that a single system-wide physical project is impractical.
- Regional projects are preferable to more limited projects, because hydrology, hydraulics, flood management system features, and land uses tend to differ among the regions, leading to unique regional issues. Focusing on the regions allows for stakeholders to work through issues as projects are developed.
- Local projects will always be needed to address specific problems. Many entities will continue to undertake these site-specific projects.

Under the comprehensive approach, projects on any scale can be pursued by any entity, as long as consideration of the river systems is highlighted and the Guiding Principles are applied.

Projects developed and implemented by USACE and The Reclamation Board in the future will generally observe the following conditions:

- Broad local support is a prerequisite to detailed planning and implementation.
- Every effort will be made to acquire needed real estate through willing sellers and eminent domain may be used only when necessary to protect public safety.
- The minimum real estate interest needed will be acquired.
- Every effort will be made to avoid, minimize or mitigate for any adverse effects of changes to the flood management system (USACE 2002b).

8.4.2.1. Potential Measures

The Study identifies a number of potential measures for improving flood management and the environment on system-wide and regional bases. The system-wide measures generally focus on better management of the existing system. Listed regional measures are a mix of management and physical measures. All are expressed in general terms with no specific locations stated (USACE 2002b).

Potential System-wide Measures

- Enhanced flood response and emergency preparedness
- Floodplain management program improvements
  - Risk-based flood mapping
  - Flood hazard mitigation for existing development
  - Flood hazard mitigation for new development
  - Other potential floodplain management measures
- System-wide reservoir reoperation
  - Coordinated reservoir reoperation analysis
  - Anticipatory reservoir release analysis
  - Operation of headwater reservoirs for flood management
  - Modifying reservoir releases for ecosystem benefits
  - Conjunctive use for flood management
  - Use of existing drainage and water supply conveyance facilities
- Multipurpose floodway maintenance
  - Research and incorporate new maintenance practices
  - Modify operation and maintenance manuals
  - Modify encroachment permits
  - Provide mitigation credits
  - Multipurpose operation and maintenance funding
  - Redesign flood management facilities (USACE 2002b)

Potential Regional Measures

- Storage measures
  - Modify reservoir operations
  - Use water delivery systems to store floodwaters
  - Use storage space in headwaters reservoir for flood management
  - Modify release capacity of dams
  - Increase reservoir storage
  - Increase conjunctive use for flood management storage
  - Establish transitory floodplain storage
- Conveyance system measures
  - Construct new levees
  - Raise levees
  - Realign levees
  - Strengthen levees
  - Establish meander zone
  - Modify weirs
  - Increase bypass capacity
  - Minimize flow constrictions and obstructions
  - Modify bypasses to more effectively convey small flood events
  - Breach levee

- Develop a flood overflow corridor or high flow bypass
- Develop side channels
- Restore oxbows
- Revegetate wetland and riparian habitats
- Reduce fish stranding
- Reconstruct river channel
- Manage sediment input from agricultural return flow
- Dredge sediment
- Modify levee maintenance (USACE 2002b)

8.4.3. Administrative Structure

Administrative structure is the responsibility of The Reclamation Board, which will provide it in the form of direction, oversight, and day-to-day management necessary for consistent and reasonable application of the Guiding Principles, minimizing costs and redundancies, facilitation of partnerships, and incremental project planning and construction. The Reclamation Board currently has all these responsibilities and authorities for the Comprehensive Plan area (USACE 2002b).

9.0 SUTTER COUNTY FEASIBILITY STUDY

9.1 INTRODUCTION

The SCFS is an effort now underway to identify and evaluate alternatives for improving flood control in Sutter County. USACE is performing the study with support from The Reclamation Board and Sutter County. The study was begun at the request of Sutter County to alleviate recurring flooding. If the SCFS identifies feasible and economically sound alternatives, it will result in a recommendation to USACE headquarters and Congress for design and construction of flood control improvements.

Past experience with the Sutter County flood control system has enabled the study to identify locations where problems are likely to occur. These locations were the primary focus of the study at the outset:

- The west levee of the Feather River from Live Oak to Yuba City. There is a potential for major flooding in Yuba City and Live Oak from this source (USACE 1999b).
- The Sutter Bypass, which exposes nearly two-thirds of the county to flood waters conducted mostly from outside the county. A Sutter Bypass levee failure occurred in 1997 that inundated more than 8 percent of the county (USACE 1999b).
- The Sutter Bypass pumping plants and their collection systems. At times of heavy local rainfall, this system's capacity is less than the inflow and ponding occurs east of the Bypass (TRB 2003).
- The east levee of the Sacramento River (pers. comm., McQuirk, 2003).
- The floodplains of the Sacramento and Feather Rivers (pers. comm., McQuirk, 2003).
- Meridian and Robbins. Meridian was saved from inundation in 1997 only by emergency levee construction when the Sutter Bypass levee failed (USACE 1999b).
- The Pleasant Grove area. Drainage is impeded by high flows in the Sacramento River and the Sutter Bypass, causing local flooding. Probable treatments involve raising and relocating structures (TRB 2003).
- The Feather River levee at Nicolaus (TRB 2003).

This report summarizes, identifies the work done to date, and describes the current status of the SCFS. It includes background information, description of the study area, details of the study, results to date and expected outcomes, completion schedule, and a short evaluation. There is one embedded figure. There are no tables and no appended material.

9.1.1 Background Information

Sutter County has historically experienced many devastating floods. Flooding problems have been less frequent since completion of the Oroville Reservoir in 1967. However, as recently as 1997, flooding has caused loss of life and severe property damage. The 1997 flood increased concerns about the adequacy of the flood management system for the Sutter County area. In response to those concerns, Sutter County requested USACE assistance to investigate alternatives to reduce future flood damages (USACE 2002d).

9.1.1.1 Study Area

Description

The SCFS study area encompasses all of Sutter County, which is located in the north-central part of the state. The Sacramento River to the west, the Feather River to the east, and the lower Bear River form a large part of Sutter County's boundaries. Its southern boundary is just downstream of the confluence of the Sacramento River with the Sutter Bypass and the Feather River. The major population center within the study area is Yuba City. Other affected communities are Live Oak, Meridian, Robbins, Pleasant Grove, and Nicolaus.

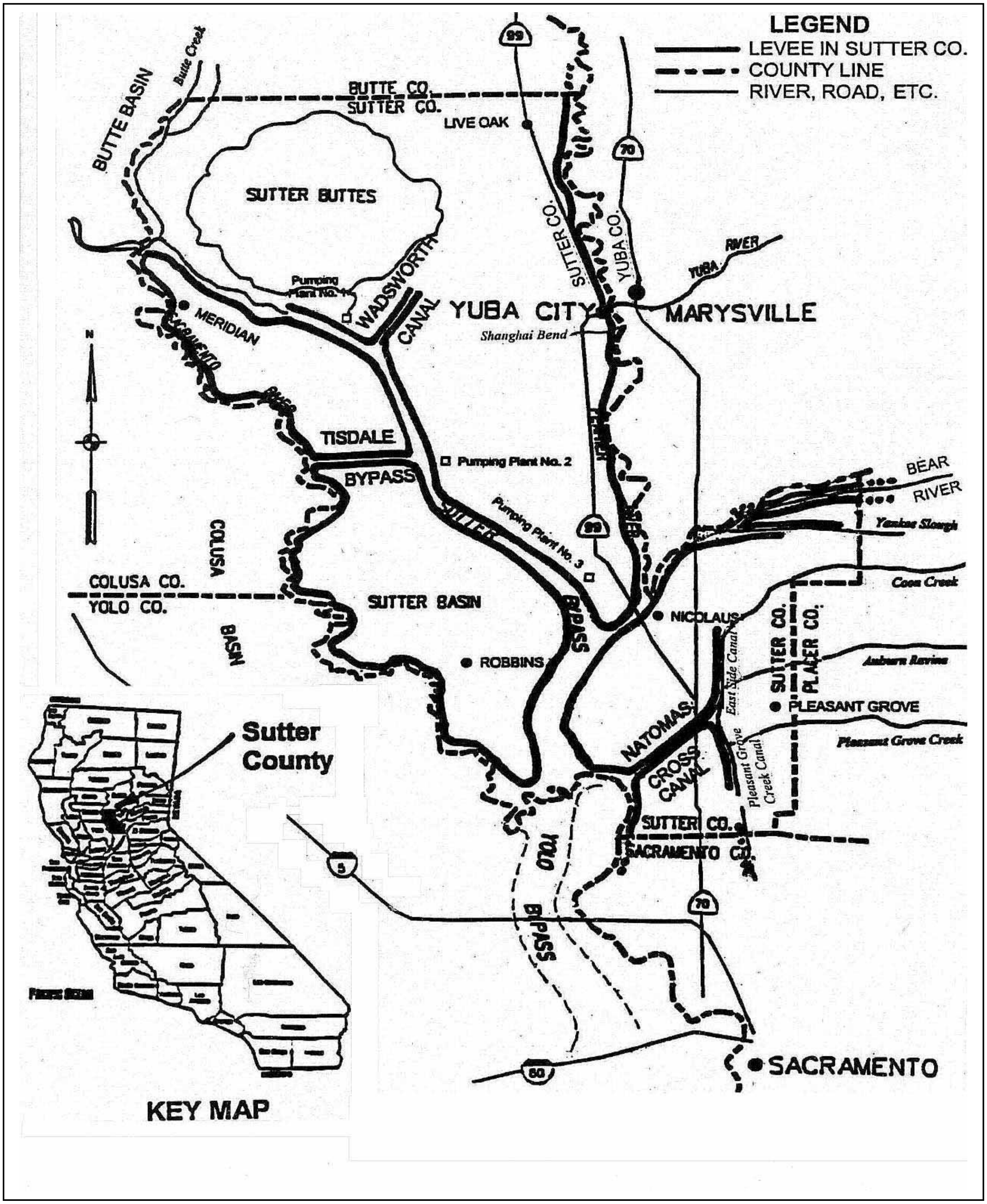
The Sutter Bypass traverses Sutter County from the northwest to the southeast and acts as flood relief for the Sacramento River. The Bypass conveys floodwaters from Butte Basin, originating mostly in the Sacramento River, and from the Tisdale Bypass, directly from the Sacramento River. There are three pumping plants and extensive drainage canals along the eastern side of the Sutter Bypass. Their function is to conduct local runoff into the Sutter Bypass from lands that drained westward into the Sutter Basin before the Bypass levee was built, including the Yuba City area. The East Side Canal and Pleasant Grove Creek Canal collect runoff from several small watersheds in the southern part of Sutter County and western part of Placer County and divert it to the Sacramento River via the Natomas Cross Canal (USACE 2002d).

The study area includes the three pumping plants and their collection system and levees and channels of the Sutter Bypass, the Feather River, the east side of the Sacramento River, the Bear River and Yankee Slough, the Tisdale Bypass, the Wadsworth Canal and collection system, and the Natomas Cross Canal and collection system. All of these are features of the SRFCP. Figure 9.1-1 shows Sutter County and illustrates these features (TRB 2003).

9.2 METHODOLOGY

9.2.1 Study Design

The primary objective of the SCFS is flood damage reduction. The study will evaluate existing and future conditions in Sutter County, identify problems and opportunities, identify planning objectives, develop a range of alternatives to reduce the damages, and analyze these alternatives. If alternatives with greater benefits than costs can be developed, the study will determine the alternative that has the highest economic benefit for the country (The National Economic Development Plan or NED Plan) and



Sources: USACE 1999b; DWR 2000

Figure 9.1-1. Locations of Existing Flood Control Facilities

recommend a project for Congress and the State Legislature to authorize. The nonfederal study participants can accept the NED Plan or may request an alternative that is economically justifiable, but must pay any cost greater than that of the NED Plan (pers. comm., McQuirk, 2003).

The study will also investigate opportunities to integrate ecosystem restoration measures into the flood damage reduction alternatives. The study will determine whether inclusion of ecosystem restoration raises the total project cost, does not substantially affect the costs, or improves the benefit to cost ratio and justifies a project where flood damage reduction benefits alone would not. The study will research potential funding sources for ecosystem restoration features beyond the scope of mitigation (TRB 2003). The final output will include an environmental impact statement/environmental impact report (EIS/EIR) (USACE 1999a).

The study procedure includes coordination and consultation with interest groups and the public in general. Public workshops and hearings have begun that will input valuable information to the study (pers. comm., Fakes, 2003b).

9.2.2 How and Where the Studies Were Conducted

The SCFS is being conducted at USACE, Sacramento District, Sacramento, California in cooperation with The Reclamation Board, an agency of the State of California in Sacramento, California and Sutter County, with county seat at Yuba City, California.

The portion of the SRFCP that protects Sutter County is quite complex, as illustrated in Figure 9.1-1. Rather than develop new hydrology and hydraulic models, the SCFS is using the models developed for the Comprehensive Study as base models. The broad assumptions used for the Comprehensive Study required refinement for this site-specific study. The SCFS made the following changes:

- Collected extensive geotechnical data, principally USACE boring logs, and developed new levee stability curves for the Sutter County levees. The new curves reveal large differences from those used in the Comprehensive Study.
- Reviewed and revised floodplain information that was at considerable variance with the actual topography.
- Accepted the hydrology used in the Comprehensive Study, but used the data to develop a new flood runoff centering at Shanghai Bend. The nearest Comprehensive Study centerings are Sacramento River at Ord Ferry, Sacramento River at Sacramento, Butte Creek near Chico, Feather River at Oroville, Yuba River at Englebright, and Bear River near Wheatland, none of which are in Sutter County. A “flood runoff centering” is a set of runoff exceedence frequencies assigned to tributary streams to represent a typical flood event chosen based on historic events.
- Revised the index points used in the Comprehensive Study, adjusting them for Sutter County conditions. Index points are locations used for data exchange among the various models of the Comprehensive Study.

- Integrated a new levee overtopping routine into the Comprehensive Study hydraulics models, providing a capability planned for the Comprehensive Study but not previously incorporated. The original Comprehensive Study models postulated levee breaks whenever stages reached a likely failure point derived from the levee stability curves (pers. comm., Fakes, 2003a).

In May 2004, SCFS produced for internal use a preliminary draft feasibility scoping meeting milestone report. The purpose of the report is to present the without-project condition of the study area. It discusses water resources problems and opportunities in the study area, states planning objectives and constraints, and identifies preliminary flood control measures and ecosystem restoration measures. The report is supported by appendices providing initial geotechnical evaluation of existing levees, existing hydrology and operations modeling, without-project floodplain delineation, and an environmental baseline (USACE 2004b).

The next step will be to develop alternatives. As alternatives are formulated, opportunities to incorporate ecosystem restoration will be explored (pers. comm., McQuirk, 2003). When an array of alternatives has been assembled, a public workshop will be held to coordinate the alternatives with the stakeholders and informal review and comments will be incorporated. The array of alternatives will then be refined to select several alternatives for full development and inclusion in the final draft feasibility study. Final steps are a 45-day public review of the draft document, final document preparation, 90-day USACE headquarters review, report filing with the Environmental Protection Agency, and project recommendation to the Chief of Engineers, the Assistant Secretary of the Army, the Office of Management and Budget, and finally Congress (pers. comm., Fakes, 2003b).

9.3 STUDY RESULTS

The SCFS draft scoping meeting milestone report tentatively identifies four non-structural measures, 14 structural flood damage reduction measures, and five structural ecosystem restoration measures and performed preliminary screening. Some of these were screened out because of high cost, economic infeasibility, or lack of local support. The measures that have been retained for further study are:

9.3.1 Non-Structural Measures

- Review the local flood warning system and the County Emergency Plan for enhancements that would provide increased response time.
- Perform flood proofing by constructing a ring levee around Yuba City.

9.3.2 Structural Flood Damage Reduction Measures

- Set back the levee along the west bank of the Feather River for five miles from a mile north of Yuba City upstream to Live Oak, and remove the existing levee.
- Construct a backup levee on the west bank of the Feather River, leaving the existing levee in place.
- Enlarge existing west levee of the Feather River from Yuba City Airport to just upstream of Yuba City, about five miles, and construct a landside support berm.
- Reconstruct known weak spots along the Feather River, Sutter Bypass, and Tisdale Bypass by inserting impermeable material into the levees.
- Resize pumping plants along the Sutter Bypass to better handle interior drainage between the Feather River and the Sutter Bypass.
- Construct an interceptor levee and channel northwest of Yuba City to conduct local floodwaters to the Wadsworth Canal, and set back the Wadsworth Canal levees.
- Construct a bypass channel from upstream on the Feather River to the upstream end of the Sutter Bypass.
- Reoperate New Bullards Bar Reservoir with increased flood control space, modified releases, and increased coordination with Lake Oroville. Reoperate Lake Oroville with increased flood control space provided by a rubber dam on the emergency spillway, and increase coordination with other reservoirs in the watershed.
- Add outlets to Englebright Dam and operate the reservoir with allocated flood control space.

9.3.3 Structural Ecosystem Restoration Measures

- Restore 227 acres of riparian vegetation at O'Connor Lakes Ecological Reserve.
- Acquire about 228 acres of private property to restore riparian vegetation near Star Bend.
- Strengthen the 90-degree bend in the west levee of the Feather River at Star Bend, and restore riparian vegetation.
- Restore riparian and aquatic habitats at Coon Creek.

An unsatisfactory initial economic assessment using the raw Comprehensive Study models and data was a principal reason for refining the input data and adjusting the models for Sutter County application. Using refined geotechnical and topographic information, the SCFS economics team developed a preliminary flood damage assessment. Work continues on the economic analysis, but the team has reached the preliminary result that levee improvements are not economically justified except in the Yuba City area on the west levee of the Feather River and the east levee of the Sutter Bypass. Selection of alternatives will focus on that area. If economically feasible alternatives can be identified, the SCFS will continue with identifying a tentatively selected plan and comparing alternatives to the without-project condition. At that point there will be another milestone report and the SCFS will continue with public review, elimination of infeasible alternatives, draft report preparation and review, final report preparation and review, EPA filing, and recommendations to USACE headquarters and Congress. (pers. comm., Kerr, 2004)

The current schedule calls for releasing the draft feasibility report for review by the public and other Federal, State, and local agencies in 2006. If the study report identifies a feasible alternative, a project could be constructed by 2010 or later, depending on federal, State, and local financing, project complexity, and other conditions (pers. comm., Baker, 2004b).

9.4 ANALYSES

The SCFS is nearing completion of the fourth year of an effort that will take more than five years, culminating in a final feasibility study report and an EIS/EIR. The broad scope of the study, illustrated by the number and variety of potential projects, and the extensive list of government, public and private organizations and individuals involved, has led to the extended study period. Progress on the study has also been delayed by the need to update the Comprehensive Study models and data, an effort that took more than a year (pers. comm., Fakes, 2003a).

The SCFS is challenged by the need to comply with the Comprehensive Study, which issued its Interim Report on December 6, 2002. The Comprehensive Study calls for all projects on the SRFCP to integrate flood damage reduction and ecosystem restoration and to evaluate the system-wide effects of any proposed changes. Update of the models for the SCFS was fully anticipated by the Comprehensive Study. The use of the Comprehensive Study models is a first step in meshing with the Comprehensive Study results (pers. comm., Fakes, 2003a).

With about two years remaining in the study, the SCFS may identify an alternative that would contribute substantially to flood damage reduction in Sutter County.

10.0 LEVEES: INSPECTION, MAINTENANCE, AND ADEQUACY

10.1 INTRODUCTION

To understand the status and importance of the Feather River levees requires a review of the history behind the development of its levee system. While construction of any levee is the initial step in support of a comprehensive flood control system, maintenance and operation of these systems is the mainstay for their continued use. As with most systems, future changes are also an integral part of the continuance for support. The intent of the following paragraphs is to review these issues providing specific information relevant to the Feather River project levees from Marysville upstream to their termination. There is one embedded figure. There are no tables and no appended material.

10.1.1 Background

There probably is no place on this planet where there is more flood control infrastructure per square mile than in California (WEF 1998). The initial steps toward this complex system began within several years of statehood. In 1855, the State Legislature passed the Reclamation District Act, in effect identifying several hundred low lying areas in the valley to be protected from flood waters only by the establishment of thousands of miles of levees.

In 1880, the State Engineer developed a flood control plan for the Sacramento Valley that included a system of levees and bypasses for transporting floodwaters away from the more populated areas. In 1917, this plan was funded and expanded, as the SRFCP (Kelley 1989). The plan was considered completed 43 years later in 1960, having established over 1700 miles of federal levees built to USACE standards. The Feather River system is an integral part of the project.

The Feather River west bank levees extend upstream to Hamilton Bend near the City of Oroville. The east bank levees extend upstream to Honcut Creek. These levees are considerably stronger than they were when the Oroville Complex was built in the 1960's due to extensive work completed in the last two decades.

Before its completion, the benefit of Oroville Dam was realized in 1964 when the dam impounded floodwaters from what became one of the most expensive floods in State history (DWR 1965). Ironically, the runoff into the Feather was the highest recorded.

10.2 LEVEE INSPECTION

DWR performs levee inspections of all SRFCP levees, whether maintained by a reclamation or levee district, as a State maintenance area, or by DWR under legislative mandate. USACE requires The Reclamation Board, as the non-federal sponsor of the SRFCP, to make these inspections. DWR staff makes the inspections on behalf of The Reclamation Board. The inspections are performed four times a year. For alternate inspections, staff from the responsible reclamation or levee districts or State maintenance yard accompanies the inspection team. The resultant inspection reports are filed with USACE twice a year. This provides a basis for a record of compliance by the appropriate maintenance agency.

The Reclamation Board is tasked with ensuring that the levees are maintained to meet USACE standards as set forth in the Code of Federal Regulations (NARA 2003). Board responsibility is limited to maintenance practices and observable levee conditions, not an assessment of internal structural integrity of the levee or its foundation.

The Feather River system project levees are shown in Figure 10.2-1. Levees were required wherever there had been any historic indication that major flooding has occurred or could occur. These levees are designed based on levee standards (USACE 2000) and the design water surface elevations established by USACE. The minimum levee freeboard is at least 3 feet. The Feather River system above Marysville has not had any levee freeboard encroachment since the project levees were built.

The critical problem and the one being addressed with all of the recent improvements has been levee failure. Most levee failures in California have been because of excessive seepage (USACE 1999c). Seepage is an issue because it can change the static stability conditions for a levee and because it can remove materials from the levee base inducing potential collapse.

Many seepage problems for the Feather River above the Bear River have been addressed by the use of the deep slurry walls that have been inserted as much as 70 feet deep. Better-designed toe drains have also been installed to carry the water away from the levee's land side, so that standing water does not weaken the structure.

10.3 LEVEE MAINTENANCE

For the areas upstream of Yuba City/Marysville, levee maintenance is the responsibility of the local reclamation and levee districts. This includes Levee District 1 of Sutter County, Levee District 9 of Sutter County, Reclamation District 10, and the Marysville Levee Commission. Reclamation District 777 released responsibility to DWR for maintenance of the project levees in both Butte and Sutter Counties. These reaches are referred to as Maintenance Areas 7 and 16, respectively (see Figure 10.2-1). DWR inspection reports for the levees of the Feather River system indicate that generally the level of attention and compliance with the USACE Manual is "Good" to "Outstanding" (DWR 2002). This means that items such as the crown roadway, slopes and toe, rock revetments, vegetative growth, rodent control, and any appurtenances have been satisfactorily maintained. The four local levee jurisdictions on the main stem of the Feather between Oroville Dam and Marysville have received either good or outstanding inspection reports for the last ten-year reporting period.

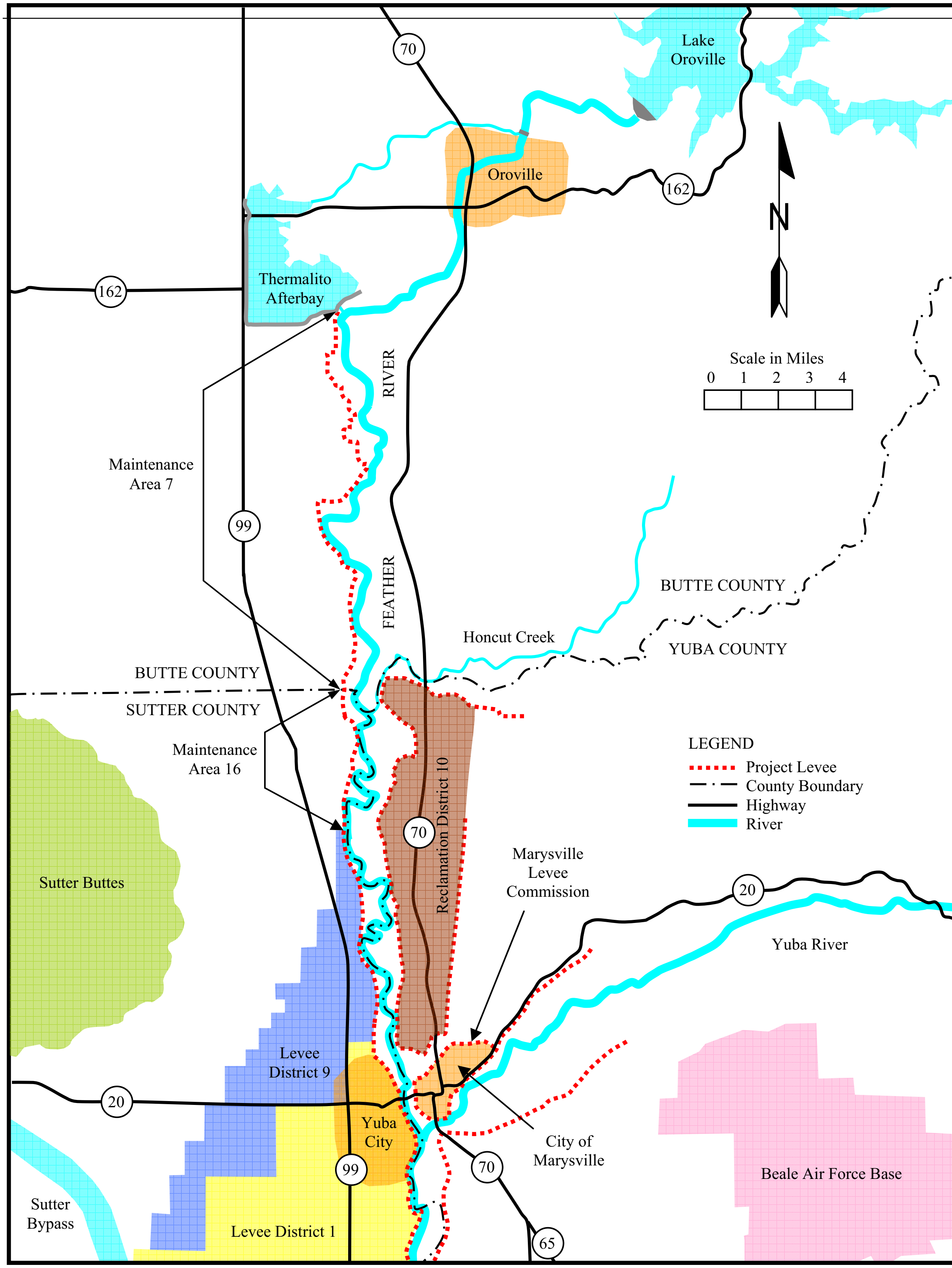


Figure 10.2-1. Location Map – Levee inspection and maintenance responsibilities.

10.4 LOCAL LEVEES

Some private levees provide local protection only and are not part of the SRFCP or the State's levee inspection program. Fitting this description is a levee in Oroville along the left bank of the Feather River located on both private and public lands. This levee was built in 1908 following the 1906 flood with the intent of protecting structures in the immediate area (pers. comm., Atteberry 2003). No specific information is available on the adequacy or inadequacy of this levee; however, the City of Oroville does perform maintenance for this levee.

10.5 LEVEE ADEQUACY

The Feather River levees are maintained consistently with their original design standards for the SRFCP's design water surface profiles. In January 2002, USACE completed the final draft of a floodplain study for The Reclamation Board based on FEMA flood insurance study requirements along the Feather River from Marysville upstream to Oroville Dam. The hydrology for this study was based on current reservoir routing criteria combined with the system analyses prepared for the Sacramento and San Joaquin Comprehensive Study. This modeling effort provided the required hydrographs used for each of the flood frequencies evaluated. The topographic data used is based on recently obtained 2' contour mapping and hydrosurveys below waterline. Calibrations of the hydraulic models were performed using historical high water marks ensuring accurate stream modeling. The completed draft study shows that the levee systems adequately satisfied FEMA criteria as well as any concerns of USACE using current hydrologic, geotechnical, and hydraulic data as well as new data created for the 100-year flood for this floodplain study. Incidentally, the USACE study shows containment of the Feather River 100-year flood flows to the waterside of the private levee in Oroville.

Since completion of this study, USACE levee certification criteria have become more stringent, addressing the concerns of the USACE levee task force and new issues including potential erosion sites. As a result, the Feather River study is going to be reassessed in 2005 pending available funding. The major concern is with the potential failure of the levee systems during a 100-year event.

10.6 ANALYSES

The floodplain study by USACE has demonstrated that the levee system adequately satisfies FEMA criteria, but subsequent USACE concerns may alter the results significantly. The maintenance reports for the Feather River levees indicate that generally the level of compliance with the USACE Manual is "Good" to "Outstanding".

Floodplain analyses and levee assessments are subject to change. The best and most current information available at the time was used. However, as new data is provided, it will be included. USACE has formed a Levee Task Force to examine levee seepage issues as they may relate to overall levee stability. When and where appropriate, the results of this effort will be integrated into the assessment of the Feather River levees.

Stream and precipitation gages, telemetry and other early warning systems allows federal, State and local agencies to predict flood intensities and timing. The number of stream gages on the Feather Basin has doubled in the last decade. This allows river forecasters to be more confident of their predictions concerning flood levels and volumes.

Better hydrologic information is combined with a system of formalized emergency response mandated by legislation passed in 1991. The State has adopted SEMS, which is now used in every locality (FEAT 1997). SEMS implementation has provided coordination and greatly increased communication among emergency responders. All counties, cities, and local districts have SEMS trained response teams who now better understand what their roles are in flood events. These teams are required to go through yearly formal exercises to maintain their level of preparation.

There have been many significant new developments in the science of fighting floods at every stage from prediction to system improvements. One of the most beneficial technologies has been the use of remote sensing to predict problem areas. Aircraft available to DWR now have the capability of flyovers to survey levees and channels during flood events. Other technologies improving flood fighting capabilities include GIS mapping and analyses, digital photography, communication tools, aerial photography, and rapid deployment support. In addition, techniques using slurry walls, stability berms, floodwalls, and seepage control systems, coupled with new materials and new installation equipment have significantly improved levee integrity.

11.0 EMERGENCY ACTION PLAN FOR OROVILLE FACILITIES

11.1 INTRODUCTION

The EAP defines responsibilities and provides procedures designed to identify unusual and unlikely conditions that may endanger Oroville Dam and its related facilities.

The plan also provides for orderly and timely notification procedures, mitigative action, and notification of the appropriate emergency management officials of a possible, impending, or actual failure of the dam. Response to any emergency will be based on the establishment of an Incident Command as defined in SEMS.

The plan may also be used to provide notification when flood releases will create major flooding.

11.1.1 Background Information

Every applicant for a license or licensee/exemptee must develop and file an EAP with the Regional Director of the Federal Energy Regulatory Commission unless granted a written exemption in accordance with Section 12.21 (a) of the Commission's Regulations. The EAP must be prepared in accordance with Chapter 6 of the FERC Engineering Guidelines (revised November 1998). Below is an excerpt from chapter six of the guidelines which conveys background information:

> *The "Guidelines for Preparation of Emergency Action Plans" were established in November 1979. The Guidelines were subsequently included as the Appendix to Order No. 122 of the Commission's Regulations, issued January 21, 1981. Then, in accordance with the provisions of Section 12.22 (a) (1) of the Commission's regulations, which states that "an emergency action plan must conform with the Guidelines established, and from time to time revised, ...", the guidelines were revised on April 5,1985, to provide more specific comprehensive guidance in the development of an EAP. Although the revised Guidelines established a specific format to assist in preparing an effective, workable EAP, it was not mandatory at that time that EAPs on file prior to April 5, 1985, comply with this format.*
>
> *The EAP Guidelines were further revised on February 22, 1988, to provide a more workable EAP that included a notification flowchart located at the front of the EAP and more clear, concise, easy-to-read inundation maps depicting the dam break scenario. In addition, a need existed for a periodic reprinting and redistribution of the EAP to improve this aspect of its dam safety program.*
>
> *Since that time, an initiative was developed to provide national (Federal, State, local) consistency in the content of Emergency Action Plans at dams throughout the country. As a result, the ad hoc Interagency Committee on Dam Safety (ICODS) prepared and approved federal guidelines for emergency action*

planning at dams which was published by FEMA in October 1998. As a result of the federal initiative, the FERC EAP Guidelines are further revised.

The EAP for the Oroville Facilities conforms to the revised guidelines which are consistent with the "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners", Mitigation Directorate FEMA 64, October 1998 (6-3.3, page 6-12).

11.2 METHODOLOGY

Because Study Plan E4 did not include specific methodology for the review of the EAP, DWR staff decided to take into consideration that: 1) the EAP meets FERC requirements and 2) the DAMBREAK analysis and resulting inundation maps had been updated after the 1997 event. The review process involved obtaining copies of the FERC engineering guidelines for the preparation of an EAP (FERC Website) to ensure that we had the latest information and that the EAP was prepared in accordance with FERC requirements. The existing EAP was reviewed to ensure that the information was current and up to date as required by FERC.

11.3 STUDY RESULTS

11.3.1 FERC Compliance

The last complete reprint of the EAP was submitted to FERC on March 10, 2000 and FERC by its letter dated April 4, 2000 acknowledged that the reformatted EAP had been prepared in accordance with the revised Chapter 6 of the FERC Engineering Guidelines. The last annual update was submitted on December 31, 2003 and FERC by its letter dated January 15, 2004 confirmed that they had updated the copies of the EAP on filed in their office.

11.3.2 DAMBREAK Analysis

The DAMBREAK analysis was conducted and the revised inundation maps were updated in October 2000, after the 1997 event, and submitted to FERC on November 29, 2000. The inundation maps are included in Appendix B.

11.4 ANALYSES

11.4.1 Existing Conditions/Environmental Setting

The regulations concerning the update and distribution of the EAP are listed below:

The licensee/exemptee/applicant for license has the option to place Appendix A of the Guidelines (Investigation and Analyses of Dambreak Floods) in a separate volume which only has to be provided to the Commission. This volume would need to be reprinted only when analyses are updated. All other sections of the EAP must be reprinted at least every five years. During the *intervening years, the licensee must maintain a line of communication with all parties involved in their EAP. Regular exchanges of information will assure that the EAP remains current and workable during an emergency. Information concerning changes in organizations, personnel, phone numbers, emergency response responsibilities, or other site specific information should be exchanged on a regular basis. Once notified of a change that would affect the EAP, the licensee is required, within 30 days of the notification, to make the necessary changes to the EAP and issue revised pages, sections, maps, as appropriate, to all parties identified in the EAP. If no interim changes are necessary, annual updates (which are to be submitted by December 31st of each year) may be made by issuing to all plan holders only those pages that contain updated information.* (Chapter 6 of the FERC Engineering Guidelines – revised November 1998)

As stated in the regulations above, all sections of the EAP other than the DAMBREAK analysis are on a five-year reprint cycle. The last complete reprint was submitted to FERC on March 10, 2000 and FERC by its letter dated April 4, 2000 acknowledged that the reformatted EAP had been prepared in accordance with the revised Chapter 6 of the FERC Engineering Guidelines. The DAMBREAK analysis was also conducted and the revised inundation maps were updated in October 2000 and submitted to FERC on November 29, 2000.

In intervening years, the EAP for the Oroville Facilities is reviewed in the fall and updates if needed are distributed to the parties identified in the EAP. The last annual update of the EAP was submitted to FERC on December 31, 2003. The next annual update is due by December 31, 2004. These annual updates cover minor changes such as updates to the notification charts.

11.4.2 Emergency Warning System

As stated above the EAP contains notification charts to be used when flood releases may create major flooding downstream of the facilities. These charts contain the contact information for responsible agencies that may need to mobilize in anticipation of these releases. For changes to project releases not requiring notification of emergency personnel a warning siren was installed on the Thermalito Diversion Dam. This siren is used to warn recreational users on the Feather River downstream and upstream of Thermalito of imminent opening and release of water through the spillway gates. The following operating procedures apply:

1. The siren shall be sounded during daylight hours only, for all increases in water releases through Thermalito Diversion Dam totaling 1,000 cfs or more;
2. The siren shall be sounded for a five (5) minute period prior to the radial gate/s opening;
3. The siren is activated from the dam control building. If no Water Technician is available, the Roving Plant Operator will activate the siren.
4. When the siren is in service, hearing protection is recommended.

12.0 PROBABLE MAXIMUM FLOOD FOR LAKE OROVILLE

12.1 INTRODUCTION

A Probable Maximum Flood (PMF) is the theoretical flood that would result from the most severe combination of precipitation and basin conditions that are reasonably possible. Therefore, the PMF represents the maximum inflow conditions for the Oroville Dam.

The most recent study by the US Army Corps of Engineers on Oroville dam PMF was done in 1980 (USACE 1980), and is summarized in this section. It was completed under an agreement between the State of California, Department of Water Resources and the US Army, Corps of Engineers. The report is an update of the March 1958 Office Report entitled, "Flood Control Hydrology, Feather River Basin, California."

12.2 METHODOLOGY

The study utilized the latest computer program (prior to 1980) HEC-1, Flood Hydrograph Package, to compute the PMF Inflow Hydrograph for Lake Oroville. It developed a mathematical computer model of the Feather River Basin including unit hydrograph, and loss rate criteria. The computer model was calibrated using the reconstitution of the observed December 1964 Flood.

The Probable Maximum Precipitation (PMP) was computed using he Hydrometeorological Report No. 36 (HMR36) published by the National Weather Service.

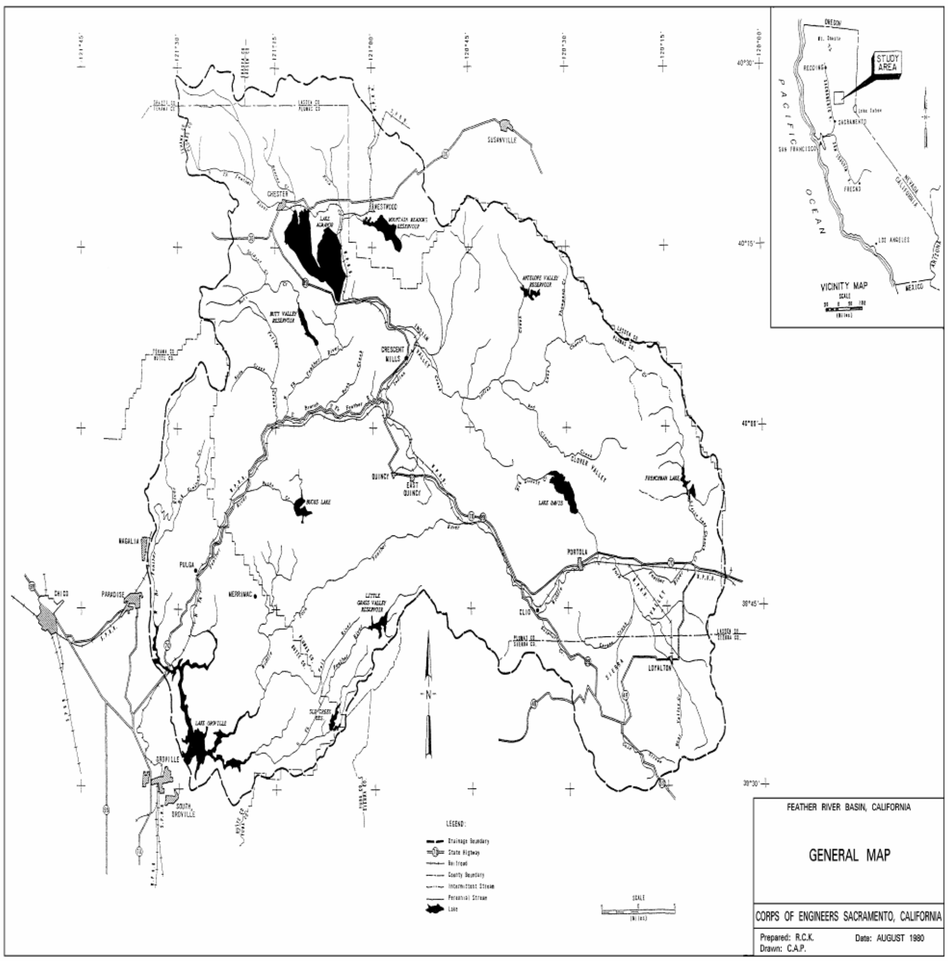
The 1980 PMF inflow hydrograph computed by the HEC-1 software program represented the runoff resulting from the PMP, based on HMR36, in the Feather River Basin.

12.3 DESCRIPTION OF THE MODEL

12.3.1 Watershed Characteristics

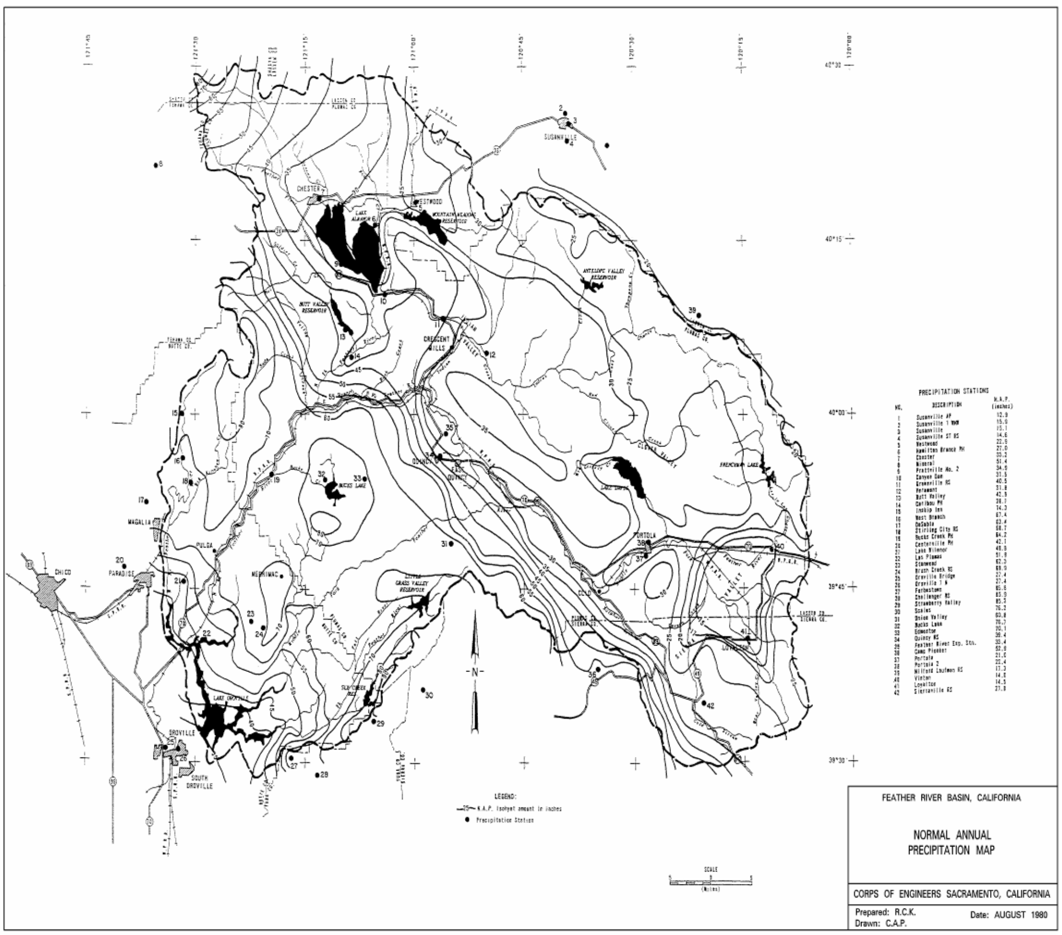
General Map of the Feather River Basin is shown in Figure 12.3-1. The drainage area is 3,607 square miles (2,308,480 acres) and is comprised of high semi-desert valleys and steep heavily timbered mountains. Normal annual precipitation varies from approximately 90 to 35 inches in the mountainous region to 15 inches in the Sierra Valley (Figure 12.3-2).

The basin area was divided into 18 sub-areas (Figure 12.3-3). These subdivisions were made at upstream reservoirs and upstream gages to facilitate analysis of the 1964 flood and the development of the PMF.



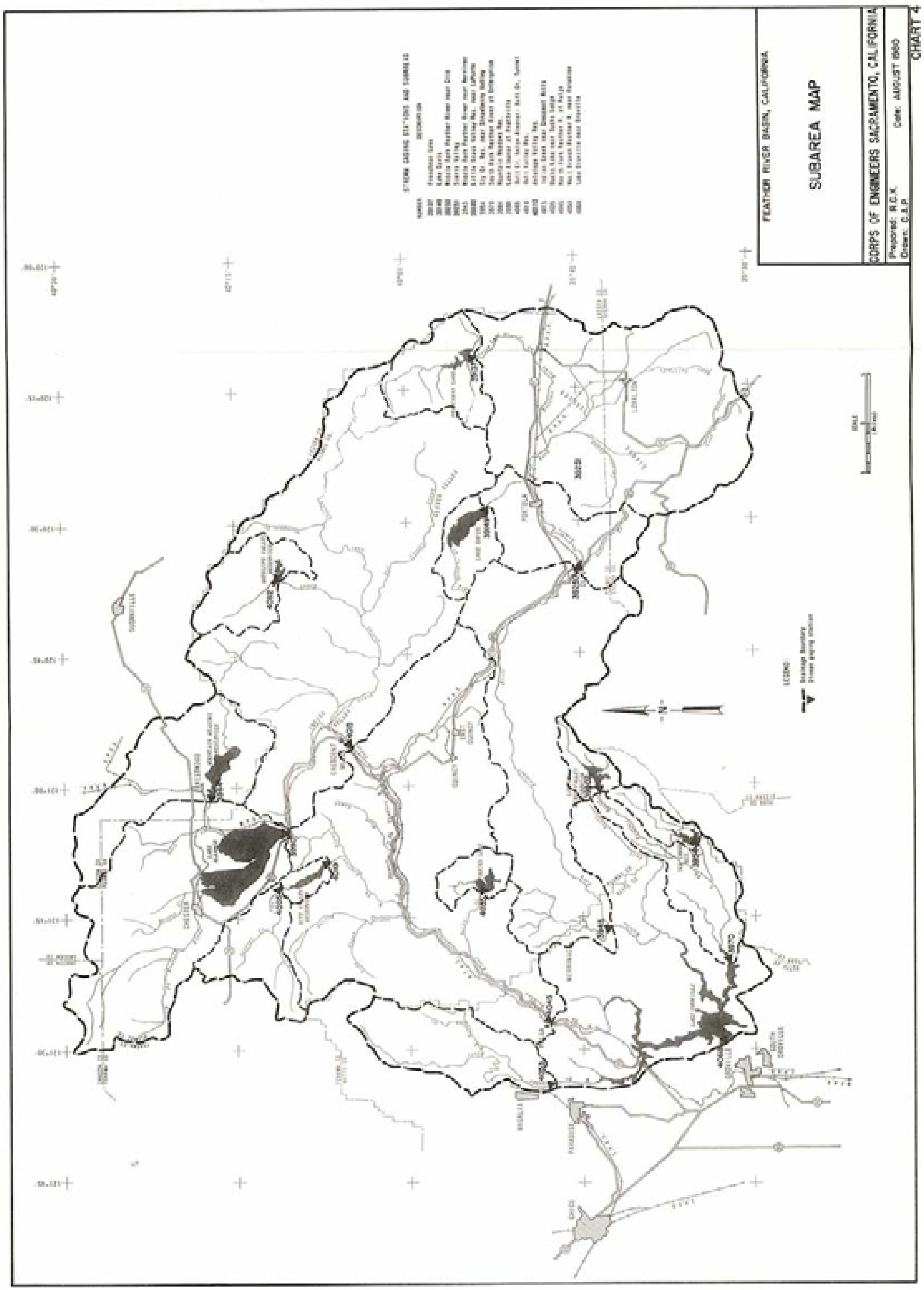
Source: USACE 1980

Figure 12.3-1. General Map



Source: USACE 1980

Figure 12.3-2. Normal Annual Precipitation



Source: USACE 1980

Figure 12.3-3 Sub-Area Map

12.3.2 Other Reservoirs in the Basin

Within the watershed of Lake Oroville, there are nine reservoirs, which were considered in the flood routing analysis. Other smaller reservoirs were neglected since they do not affect the flood flows significantly. The reservoirs were assumed to be filled to the crest at the beginning of the PMF. Butt Valley Dam was assumed to have a power release of 2,000 cfs while the outlets of other reservoirs were assumed inoperative and closed.

Table 12.3-1 Reservoirs in the Feather River Basin

Reservoir	Storage Capacity (AF)
Mountain Meadows	7,800
Lake Almanor	1,308,000
Butt Valley	49,700
Bucks Lake	101,900
Antelope Valley	22,600
Frenchman Lake	55,500
Lake Davis	84,400
Little Grass Valley	74,400
Sly Creek	56,200
	1,760,500 acre-feet

12.4 RECONSTITUTION OF THE DECEMBER 1964 FLOOD

The purpose of Reconstituting the December 1964 Flood was to verify and calibrate the unit hydrograph, loss rate and the base flows For this purpose the criteria adopted in the 1958 report was used because it had satisfactorily reconstituted six previous floods. Major elements of the 1964 Flood Reconstitution effort in the 1980 PMF Study are given below:

- The watershed area was divided into 18 sub-drainage areas, and their effect on the reservoir flood routing (Figure 12.3-3) was considered.

- The storm precipitation was distributed using Isohyetal maps of the storm and 18 stream gauging stations throughout the drainage area. (Figure 12.4-1)

- A moderate snow pack existed over the basin prior to the storm, with snow depths varying from 0 inches at elevation 4,000 feet (msl) to 60 inches at elevation 8,000 feet (msl). Temperatures were based on Central Sierra Snow Laboratory data and a lapse rate of 3^{o}F per 1,000 foot drop in elevation was assumed. The influence of snow pack on runoff was determined using the Bureau of Reclamation method presented in Engineering Monograph No. 35, “Effect of Snow Compaction on Runoff from Rain on Snow”, dated June 1966.

- New unit hydrographs for various sub-basins were developed using the modified Los Angeles District S-Curve procedure, presented in Technical Bulletin No. 5-550-3, “Flood Prediction Techniques.”, dated Feb. 1957.

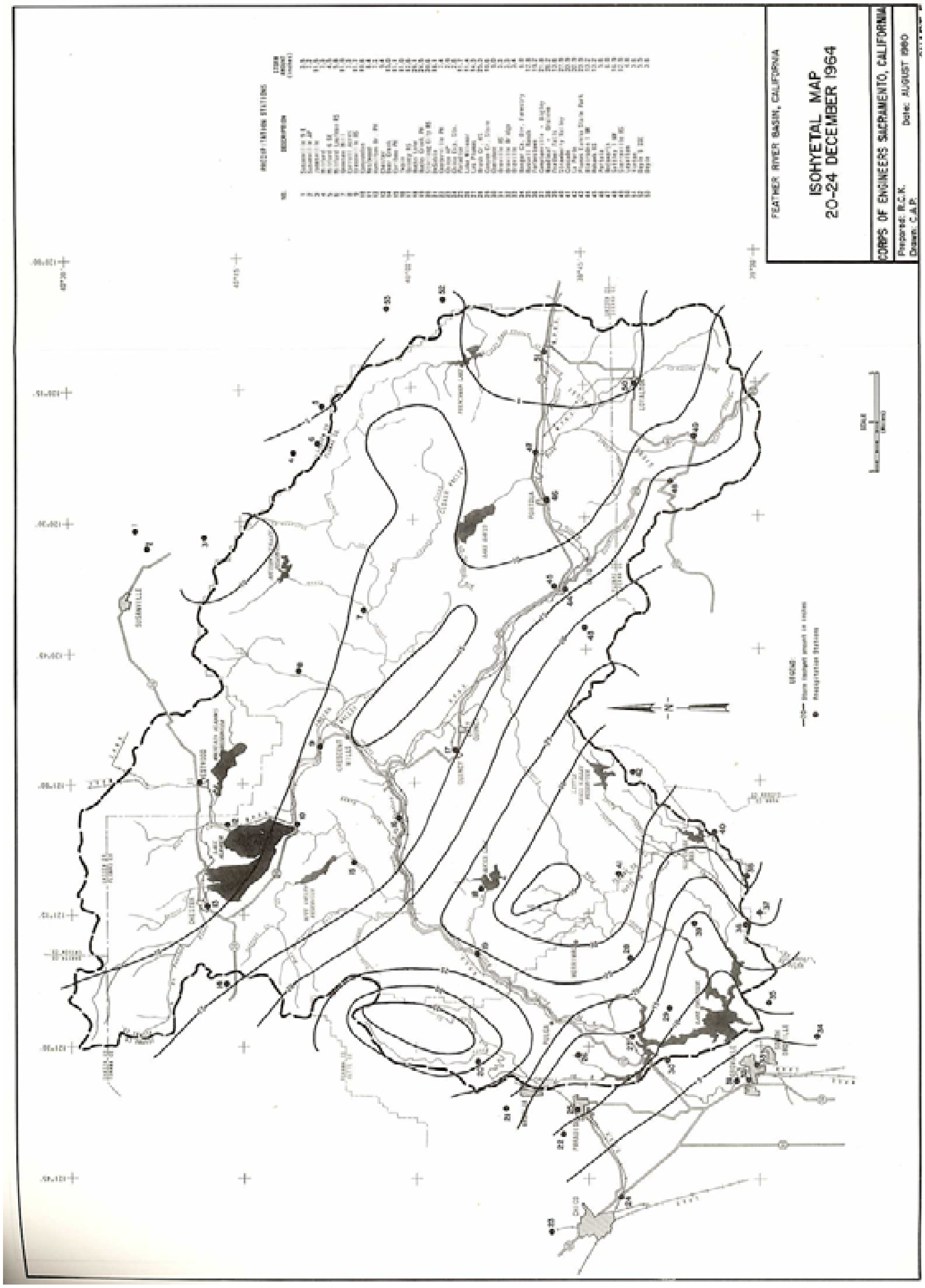
- Loss rates used in 1958 report were adopted. However, the Loss rates for North Fork Basin were adjusted slightly for better flood reconstitution.

- Baseflow used in the 1958 report was equal to the recession amounts from the antecedent storms. For the 1964 Flood, baseflow is quite small. However for the PMF, it is equal to that in 1958 report and is much larger than the baseflow in 1964.

- Flood routing consisted of Stream reach routing and Reservoir routing. A flow routing diagram is shown in Figure 12.4-2. For most reaches Muskingum routing method was used. The modified-puls method was used for routing in reaches where the storage has significant effect, such as Sierra Valley. Modified-puls method was also used for North Fork Feather River. This was necessary to adequately define the attenuation of the dam-break hydrograph from Butt Valley Dam which is assumed to fail during the PMF.

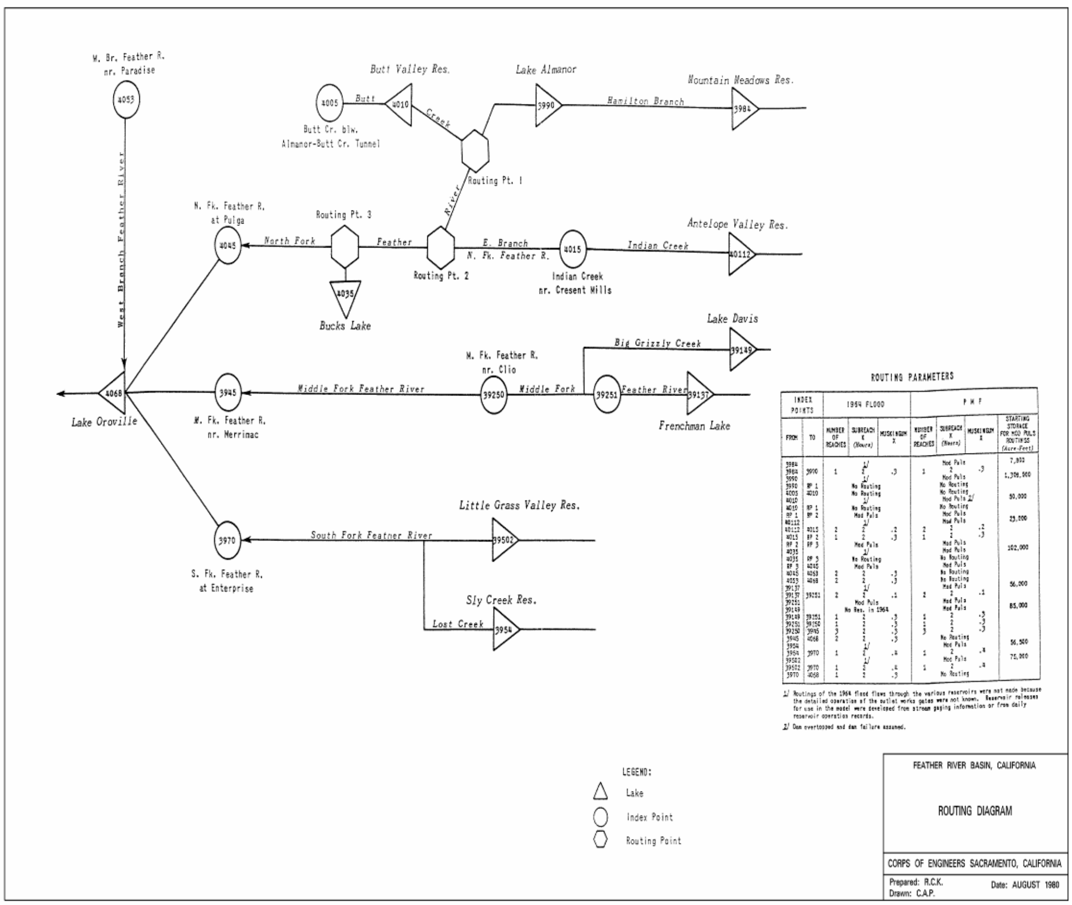
- The Flood flows were routed through the nine reservoirs listed in Table 12.3-1. For the PMF routing, the reservoirs were assumed to be filled to spillway crest at the beginning of the flood, with outlets inoperative and closed. However, Butt Valley Dam was assumed to have a power release of 2000 cfs.

Results of reconstitution of 1964 floods (Figure 12.4-3 and 12.4-4) were considered to be satisfactory, and they served to verify the unit hydrograph, loss rate, baseflow and flood routing criteria. The mathematical model of the basin was thus judged adequate to compute the PMF.



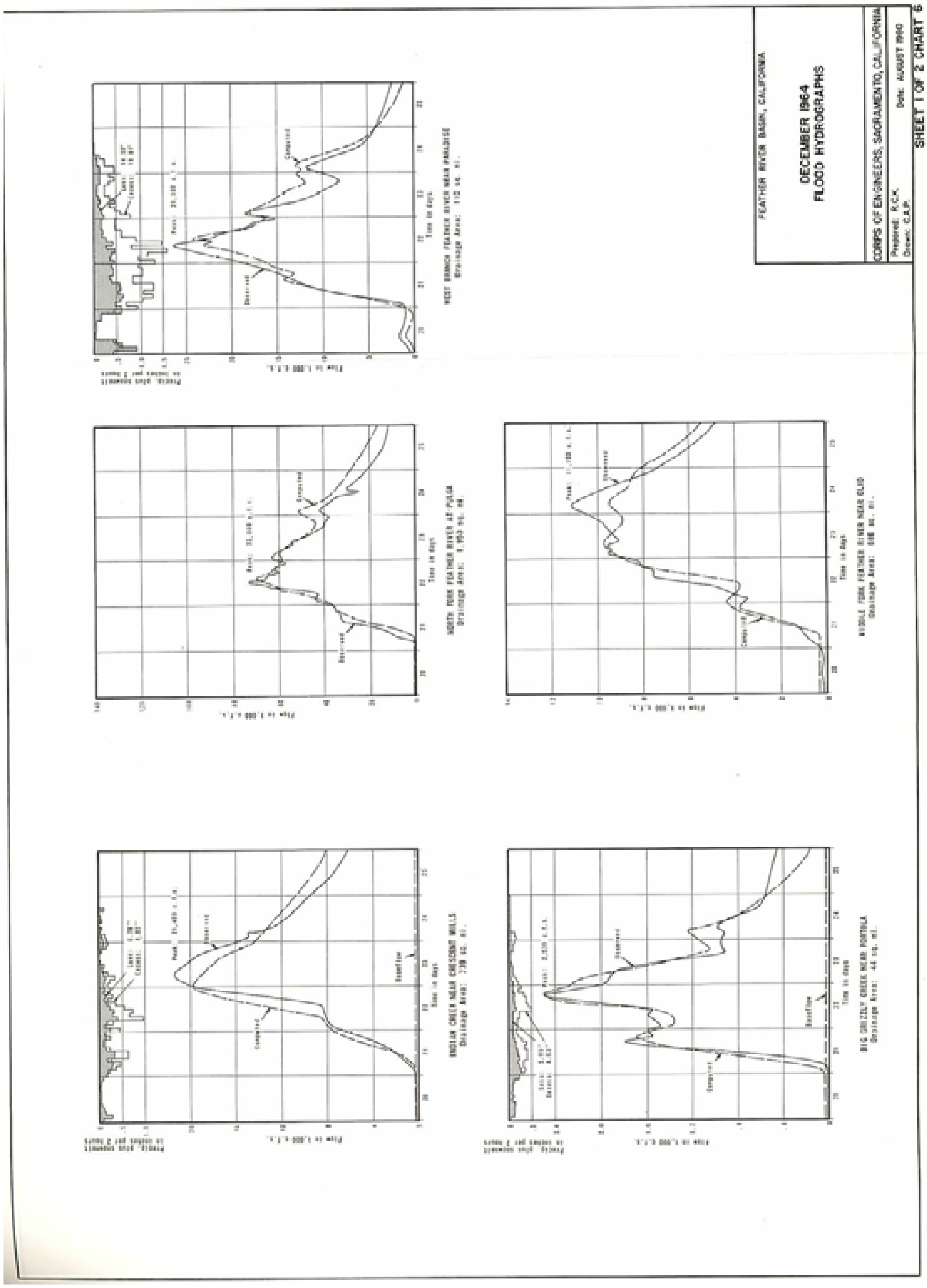
Source: USACE 1980

Figure 12.4-1 December 1964 Storm Isohyetals



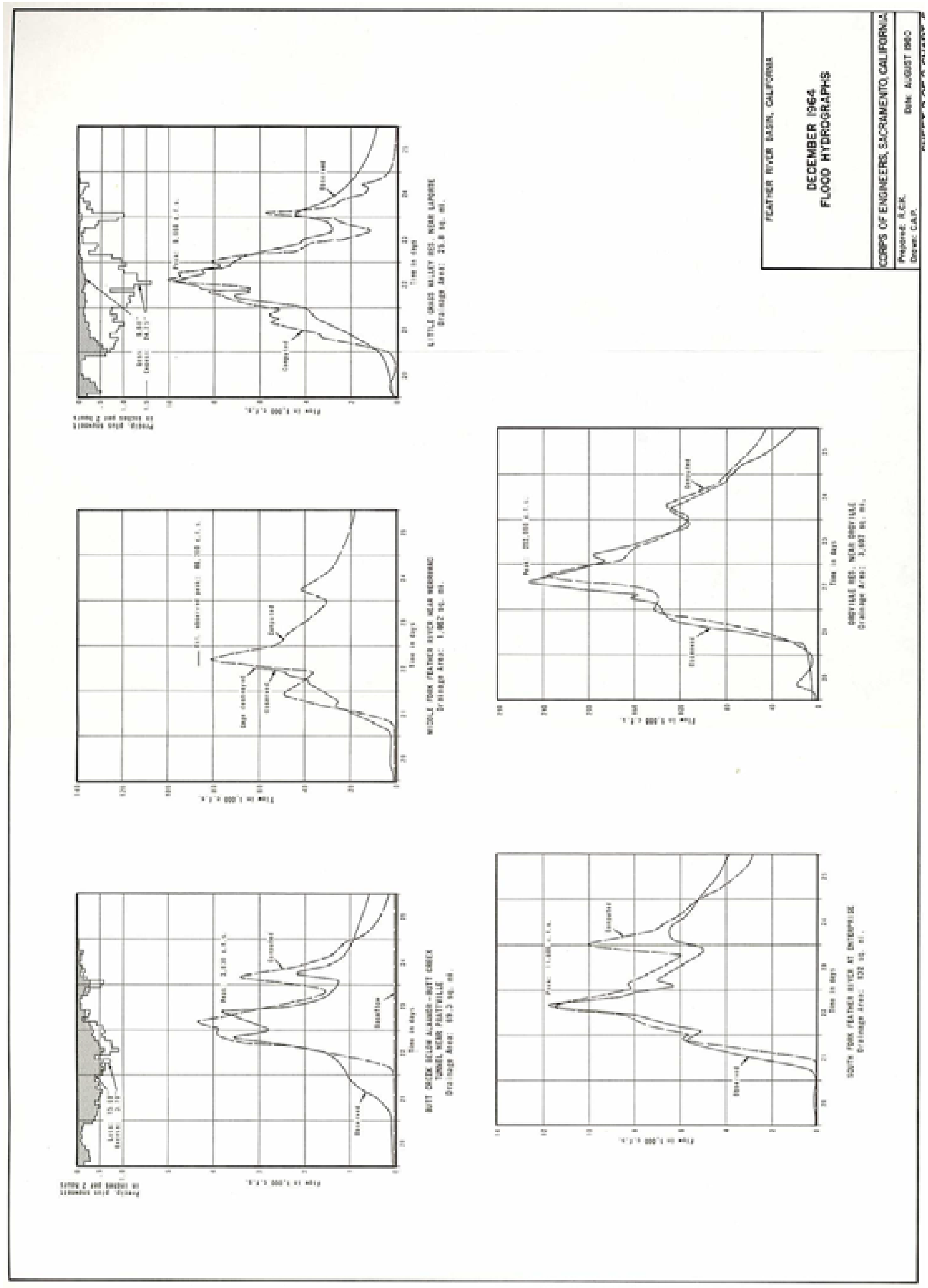
Source: USACE 1980

Figure 12.4-2 Routing Diagram



Source: USACE 1980

Figure 12.4-3 Dec. 22-25, 1964 Flood Comparison-Sheet 1



Source: USACE 1980

Figure 12.4-4 Dec. 22-25, 1964 Flood Comparison-Sheet 2

12.5 THE PROBABLE MAXIMUM PRECIPITATION (PMP)

The PMP is the theoretical maximum possible precipitation for a given duration that is physically possible for a given storm area at a geographical location at a certain time of the year. Precipitation may be either rain or snow.

The 1980 PMP estimate of 28.9 inches, occurring in January-February, was developed using the Hydrometeorological Report No.36, "Interim Report-Probable Maximum Precipitation in California", with revisions published October 1969. The precipitation was centered over the watershed above Oroville.

12.6 THE SNOW EFFECTS ON THE FLOODING

Snow was assumed to exist prior to the occurrence of the probable maximum storm. Snow depths varied from zero at 4,000-foot elevation to about 60 inches at the 8,000-foot elevation. The density of the snow pack where compaction ceases and drainage begins was assumed to be 40 percent. The snowmelt over the entire watershed contributed an additional 4.5 inches of total water above the PMP of 28.9 inches.

12.7 THE PROBABLE MAXIMUM FLOOD (PMF)

The PMF is a function of the Basin Model, the PMP, snow melt, and the routing through the upstream reservoirs. All reservoirs were assumed capable of passing the storm amount through the spillways with the exception of Butt Valley and Bucks Lake Dams. Butt Valley and Bucks Lake Dams would be overtopped as indicted below:

Bucks Lake Dam, a Rock Fill structure, will be overtopped by a maximum of 0.4 feet for 8 hours. It was assumed that this dam will withstand the overtopping.

Butt Valley Dam, a Hydraulic Fill structure, will be overtopped by a maximum of 2.4 feet for 32 hours. It was assumed that Butt Valley Dam would not withstand the overtopping and would fail.

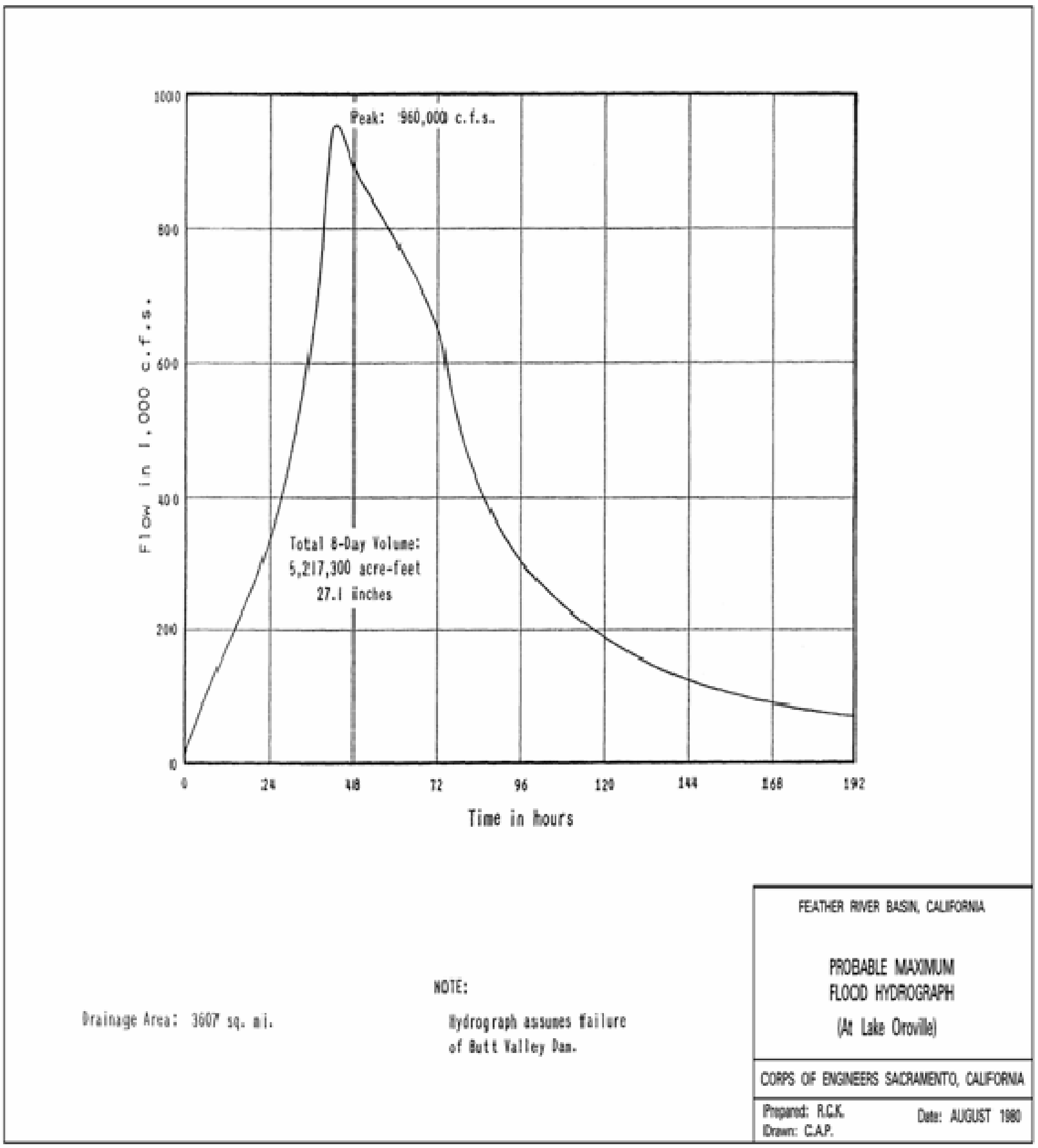
The final PMF inflow hydrograph to Lake Oroville, which includes the failure of Butt Valley Dam is shown on (Figure 12.7-1).

The Peak PMF inflow to Lake Oroville is 960,000 cfs.

Table 12.7-1 Summary of the PMF Study by USACE 1980

Drainage Area	3607 square miles.
Sub-basins	18
PMP	28.9 inches.
Month of Storm:	January-February
Basis for PMP:	HydroMeterological Report No, 36
Butt Valley Dam:	Failed

Snowmelt:	4.5 inches
Peak Inflow:	960,000 cfs
Total 8-day Volume	5,217,300 acre-feet.



Source: USACE 1980

Figure 12.7-1 Probable Maximum Flood Hydrograph

12.8 REFINEMENT OF THE PMF STUDY BY DWR (1983)

In April 1983, DWR published a Study, "North Fork Feather River Flood Study, Investigation of Hypothetical Butt Valley Dam-Break Flood, and Lake Oroville Wind Wave Analysis". (DWR 1983) This study consisted of the following parts:

12.8.1 Butt Valley Dam Break Analysis

Computer program DAMBRK, developed by the Hydrologic Research Laboratory of the National Weather Service (1982) was used to model the dam break. It models the dam breach, routs the flood through the downstream channel, and computes the depth of flood using the dynamic wave mathematical simulation. In determining the maximum discharge an instantaneous failure was assumed in a partial breach of Butt Valley dam. This conservative assumption results in 65% higher discharge than a breach that forms in one hour.

PMF conditions during the event resulted in large flows in addition to the dam-break flood. The dam-break flood may be visualized as a rapidly rising wave superimposed on the natural flood. Before entering Lake Oroville, the dam-break flood rises from the natural flow to a peak over a period of 2.5 hours and recedes in 3 hours. The wave is reduced in height as it enters the upper parts of Lake Oroville and is dissipated in the widening and deepening arm of the reservoir. The wave does not travel through Lake Oroville to Oroville Dam. The water surface of the main body of the lake remains level.

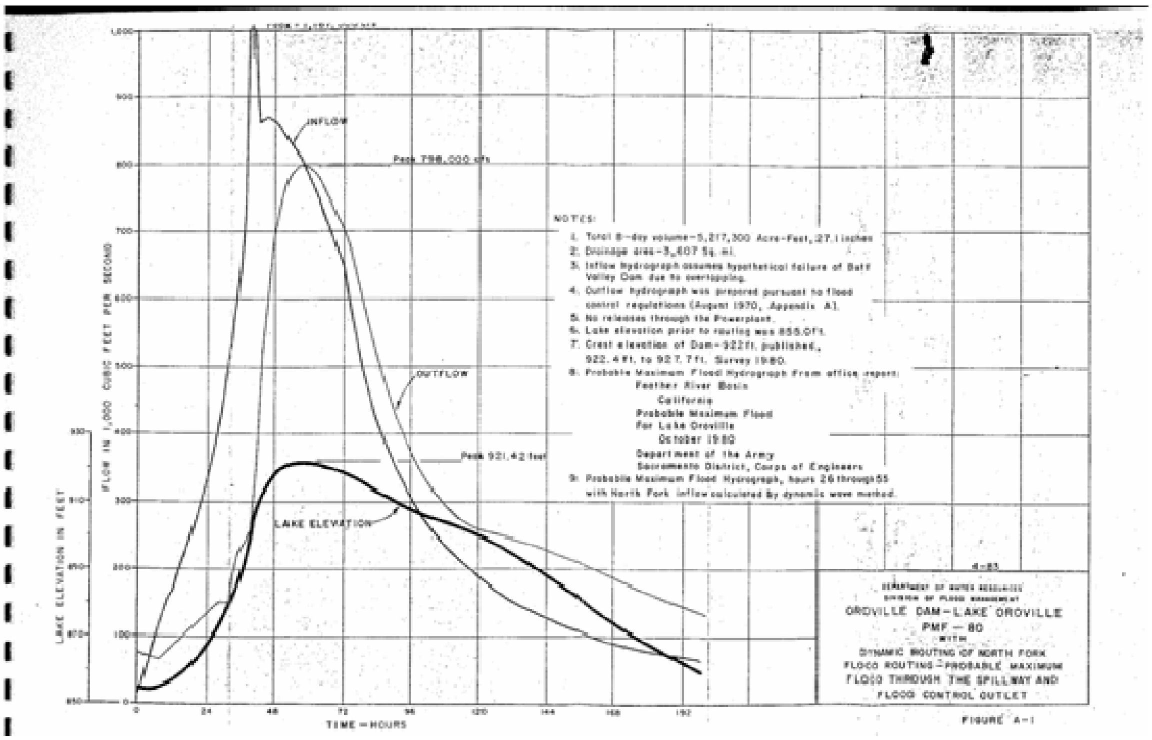
The peak inflow into Lake Oroville, including the flow from Butt Valley Dam failure computed in this study was 1,167,000 cfs and occurs at hour 40.

12.8.2 Lake Oroville Storage Routing

The inflow Hydrograph, natural PMF plus Butt Valley Dam-break Flood, was routed through Lake Oroville. The results of routing are shown in Figure 12.8-1 and listed below:

Table 12.8-1 Oroville Dam PMF with Dynamic Routing (1983)

PMP:	28.9 inches
Snowmelt:	4.5 inches
Peak Inflow:	1,167,000 cfs (Occurs at hour 40)
Eight day Inflow Volume:	5,217,300 acre-feet
Initial Elevation:	855 feet
Maximum Reservoir Elevation:	921.4 feet (Occurs at hour 58-59)
Peak Outflow	798,000 cfs (Occurs at Hour 58-59)



Source: DWR 1983

Figure 12.8-1. PMF (1980) with Dynamic Routing of North Fork

12.8.3 Lake Oroville Wind Wave Analysis

The study estimated wind waves during the PMF. Possible winds over Lake Oroville were estimated from climatological data. The dam is sheltered from strong southerly winds typical of a major storm like the PMF storm. The dam is exposed to northeasterly winds. Strong northeasterly winds have been observed in the area during dry weather, generally in Fall.

The winds during the PMF storm blow from a southerly direction. They may shift in the northeasterly direction roughly 3 to 4 hours before the end of storm.

Maximum speed of wave generating northeasterly winds is estimated to be 25 mph. In the worst case scenario, the maximum wave run up on the dam face is expected to be 2 feet.

This run up will develop when rainfall has nearly all stopped-(hour 69), which is about 10 hours following the peak stage (921.4 feet). At that time the reservoir has receded to 919.6 feet.

12.8.4 Residual Freeboard

At the time of maximum wind wave run up, there is residual freeboard of 2.8 feet at the abutments and even greater at the center of the dam crest. Therefore no overtopping of the dam is expected.

12.9 STUDY TO UPDATE AND ANALYZE THE PMF FOR OROVILLE DAM

12.9.1 Introduction

This study is carried out in response to the recommendation of the Department of Water Resources Director's Safety Review Board. In the 1999 Independent Review of Safety of Oroville Dam, Thermalito Diversion, Forebay and Afterbay Dams, Feather River Fish Barrier Dam, the Board recommended:

"5.4 SPILLWAY (Page 8) -- For development of an updated Probable Maximum Flood and the routing of the flood considering full operation of all spillway gates and the effect of non-operation of one and two spillway gates. The routing studies need to evaluate the actual minimum residual freeboard on Oroville Dam, Bidwell Canyon Dam, and Parrish Camp Dam taking into account the surveyed crest elevations including camber at each dam."

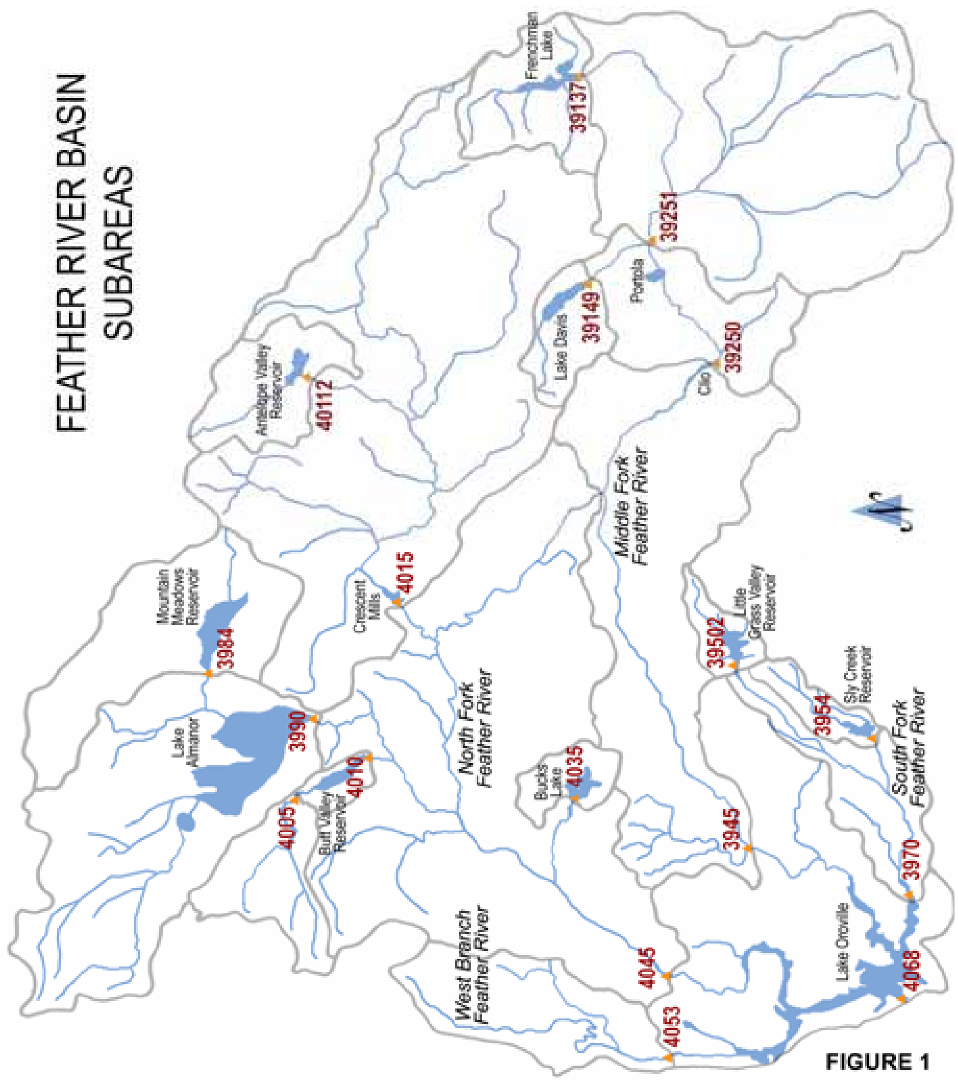
A Probable maximum Flood (PMF) is the theoretical flood that would result from the most severe combination of precipitation and basin conditions that are reasonably possible. Therefore, the PMF represents the maximum inflow conditions for Oroville Dam.

Since the previous estimate of PMF in 1980, there have been significant advances (discussed below) in the science of estimating the precipitation and the software for computing the PMF. The updated PMF developed in this study incorporates those advancements.

12.9.2 Study Description

12.9.2.1 Basin Description

The Feather River basin above Lake Oroville encompasses about 3600 square miles of drainage area. Outflow from Lake Oroville ultimately drains to the Lower Sacramento River, and then to the Sacramento-San Joaquin Delta. Basin elevations range from about 850 feet at Oroville Dam to near 10,000 feet in the Northwest corner near Mount Lassen. Much of the drainage area is between 5,000 and 6,000 feet in elevation. Runoff from the drainage area is a combination of rain and snowmelt. During the development of the original HEC-1 model (1980), the basin was split up into eighteen sub-areas based on topographic and hydrographic features. The 2003 study used the same sub-areas. They are shown in the basin schematic in Figure 12.9-1.



Source: DWR 2003a

Figure 12.9-1: Feather River Basin and Subarea Delineations

12.9.2.2 Updated Probable Maximum Precipitation estimates (HMR 59)

As stated before the PMP is the theoretical possible maximum precipitation for a given duration that is physically possible for a given storm area at a geographical location at a certain time of the year. Precipitation may be either rain or snow.

In the 1980 PMF study, and the 1983 refinement of that study, the PMP was computed using the data and procedures presented in Hydrometeorological Report No. 36 (HMR 36) published by the National Weather Service.

At the time of this 2003 Study, HMR 36 was superseded by HMR 59 "Probable Maximum Precipitation for California: Calculation Procedure" published in 1998. This required that a new PMP be developed for the Feather River Basin using HMR 59. The new estimates are shown below.

Table 12.9-1 Probable Maximum Precipitation (HMR 59) Depth per Sub-area

Subarea	Area (mi^2)	Avg.PMP Index Depth (in.)
3984 Ab Mtn Meadows	148.0	13.00
3990 Ab Almanor	343.0	14.37
4005 Ab Butt Valley	69.3	18.97
4010 Butt Valley R	14.1	15.30
40111 Ab Antelope	68.6	14.10
4015 Ab Crescent Mil	670.4	14.01
4035 Ab Bucks	28.6	27.80
4045 Ab Pulga	611.0	20.42
4053 W Branch	110.0	30.00
39137 Ab Frenchman	81.1	15.00
39251 Ab Sierra Val	446.9	12.63
39148 Ab Davis	44.0	14.80
39250 Ab Clio	114.0	13.98
3945 Ab Merrimac	376.0	23.71
4068 Ab Oroville	350.0	28.09
3954 Ab Sly Cr	24.0	31.10
3950 Ab Ltl Grass Va	25.8	28.00
39701 SF Ab Enterpri	82.2	30.00

Source: DWR 2003a

12.9.2.3 Upgraded software (HEC- HMS) for Flood Hydrology

In the 1980 PMF study the computer program HEC-1, running on a main frame computer, was used. However for the 2003 study, an upgraded version of HEC-1, HEC-HMS, which is windows based and runs on a PC, was used. This required the original HEC-1 model input data to be converted into an HEC-HMS input data file.

12.9.2.4 Comparison of the old (HEC-1) and new (HEC- HMS) Programs

The basic philosophy for conducting the updated PMF study was to use the original unit hydrograph, loss rate, base flow, flood routing, and storm pattern data as presented in the 1980 report and change only the precipitation data in accordance with HMR 59 criteria.

To make sure that no significant difference occurred due to changing computer programs, a test PMF was computed using the new HEC-HMS Program (PC) with old HMR36 PMP and compared with the 1980 PMF which used the HEC-1 Program with the old HMR36 PMP.

The peak flow and 72-hour volumes of this test PMF were compared with those of the original 1980 (HEC-1) PMF. The results, (see Figure 12.9-3), show that the HEC-HMS produced an inflow peak 0.8% higher, and a 72-hour inflow volume 5.5% larger than the original results. These differences are considered very minor. Therefore, the two versions of the program were considered to yield similar results.

12.9.2.5 Verification of the Model

The original HEC-1 model had been calibrated using the observed December 1964 flood. The HEC-HMS model also satisfactorily duplicated those results.

The HEC-HMS model was also tested to see how well it reproduced the January 1997 event. The 1997 storm data was entered into the HEC-HMS model. The results are shown in Table 12.9-2 and Figure 12.9-5.

Table 12.9-2 HEC-HMS Model 1997 Event Reproduction

Hydrograph	Peak Flow	72-hr Volume
Observed 1997 Inflow	341,744 cfs	1280 TAF
HEC-HMS 1997 Reproduction	342,283 cfs	1250 TAF

The results in Table 12.9-2 show that the HEC-HMS model produced a peak flow that is less than 1% higher than the observed peak, and a peak 72-hour volume that is 2% smaller than the observed volume. Therefore, for the January 1997 flood, the computed (HEC-HMS) and observed inflows into Lake Oroville compare favorably.

12.9.2.6 Estimating the PMF Inflow Hydrograph

After testing the new model (HEC-HMS), a PMF inflow hydrograph was generated using the new HMR59-based estimate of PMP. The PMF inflow hydrograph describes the theoretical maximum inflow over time, and the total volume of water flowing into Oroville reservoir. These volumes are then applied to the reservoir dimensions to determine the rate of rise in the water level and the flow through the spillway and outlet facilities.

12.9.3 Preliminary Results

In the 1980 PMF study, the PMP was large enough to cause overtopping (and failure) of Butt Valley Dam. This increased the PMF at Lake Oroville, and superseded the PMF used to design the emergency spillway in 1968. With HMR 59, the updated PMP was small enough compared to the original analysis that Butt Valley Dam was no longer overtopped.

Preliminary results, (pending regulatory approval), indicate that the 2003 PMF Peak inflow is less than the 1980 PMF estimates by the US Army, Corps of Engineers. Results are shown in Table 12.9-3 below and in Figure 12.9-2.

Table 12.9-3 HEC-1/HEC-HMS Model Results Comparison

Run Description	Peak Flow	72-hr Volume
1968 Spillway Design PMF	720,000 cfs	2510 TAF
1980 HEC-1 Model (HMR 36)	**873,000 cfs**	**3706 TAF**
HEC-HMS Model (HMR 36)	890,000 cfs	3768 TAF
Updated HEC-1 Model (HMR 59)	721,000 cfs	3069 TAF
HEC- HMS Model (HMR 59)	**725,000 cfs**	**2996 TAF**

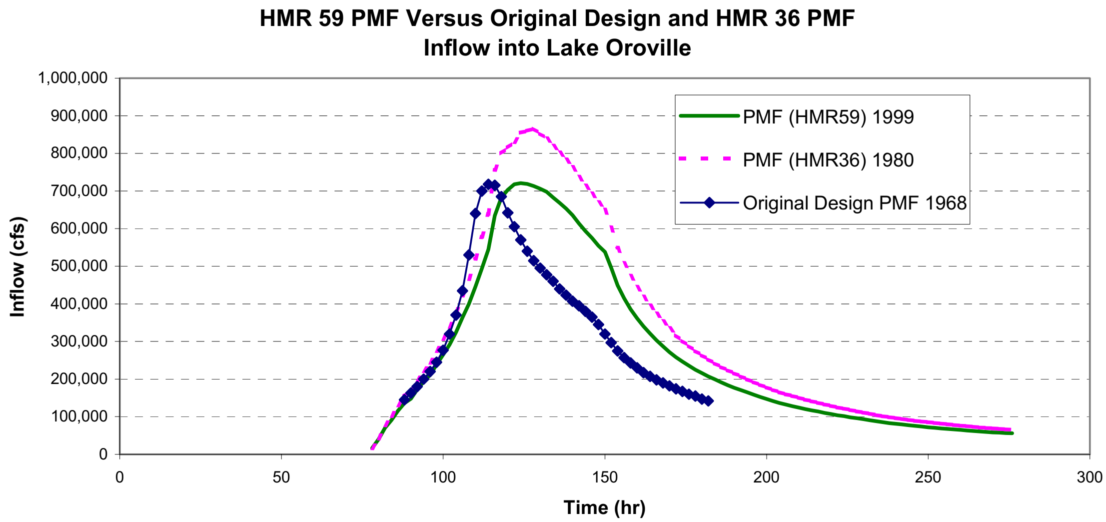
A comparison of the updated PMF inflow hydrograph (HEC-HMS) against the PMF inflow hydrograph computed by using the old model (HEC-1) and new HMR59 PMP is shown in Figure 12.9-4. Clearly, the old HEC-1 and the new HEC-HMS programs produce essentially identical hydrographs.

The difference in the 1980 and 2003 PMF inflow hydrographs is due to the change in precipitation based on HMR 36 and HMR 59 respectively.

The HEC-HMS model is recommended as an updated, calibrated model and the resulting PMF inflow hydrograph is recommended for use in subsequent operational studies for Lake Oroville.

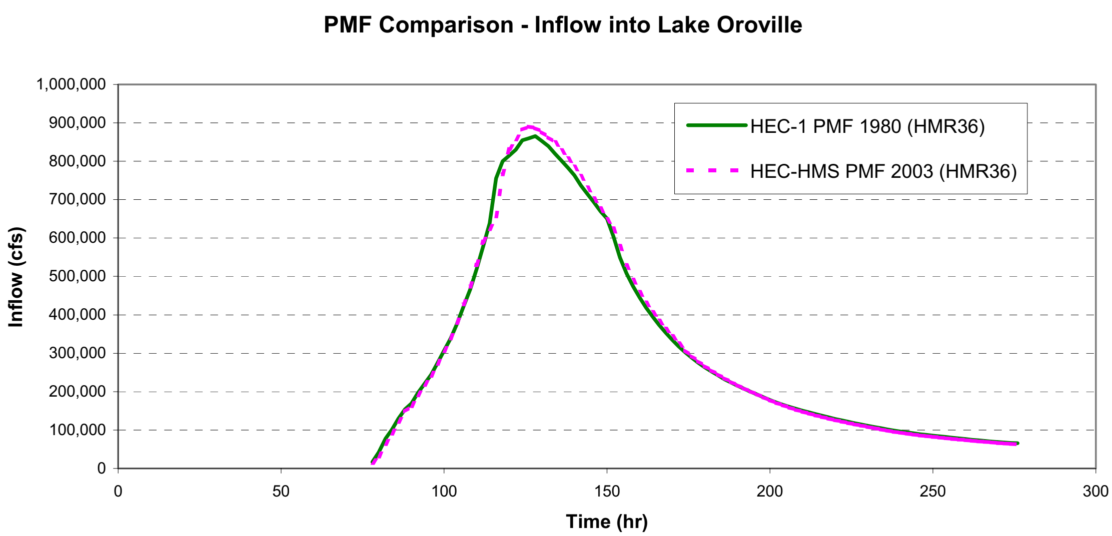
12.9.4 Flood Routing

The PMF routing considering full operation of all spillway gates and the effect of non-operation of one and two spillway gates is under way at this time.



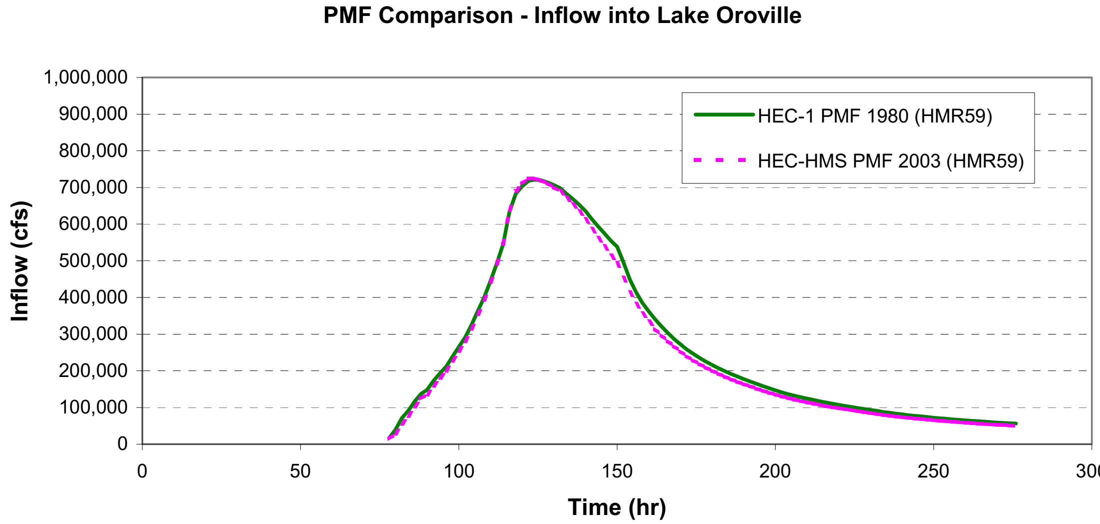
Source: DWR 2003a

Figure 12.9-2. HMR59 PMF vs. Original Design PMF and HMR36 PMF



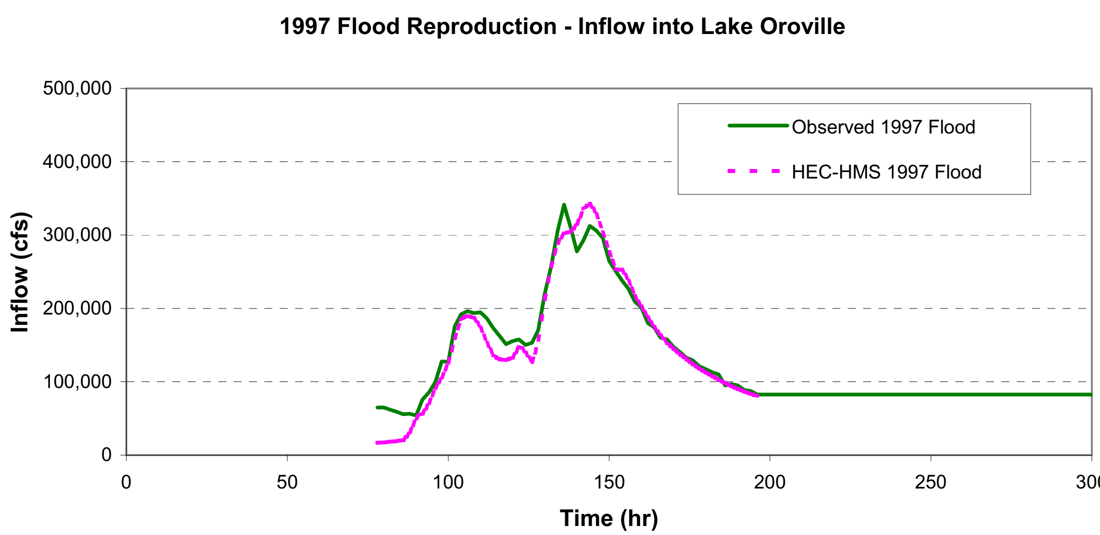
Source: DWR 2003a

Figure 12.9-3 HEC-HMS PMF 2003 (HMR36) vs. HEC-1 PMF 1980 (HMR 36)



Source: DWR 2003a

Figure 12.9-4. HEC-HMS PMF 2003 (HMR59) vs.HEC-1 PMF 1980 (HMR 59)



Source: DWR 2003a

Figure 12.9-5. HEC-HMS 2003 Reconstitution of 1997 Flood

13.0 STUDY RESULTS

13.1 PRODUCTS/DELIVERABLES

There were four products identified in the study plan. They were: (1) inundation maps for various flows under present conditions, (2) estimates of 100-yr water surface profiles, (3) identification of potential measures to improve flood protection provided by the Oroville Facilities, and (4) quantitative and qualitative effects of the flood protection measures.

The inundation maps are found in Appendix A, Figures A-5 through A-16. The water surface profiles are also in Appendix A, Figures A-2 through A-4. A detailed discussion of how these figures were generated and their intended use is found in Section 5.0 of this report.

Various measures to improve flood protection in the region have been identified by existing or in-progress studies. The YFSFCP identified 37 measures (elements) some involving the Oroville Facilities (Table 7.3-1). Of the 37 measures only five remain and of those five only one involves the Oroville Facilities. The remaining measure is an offshoot of forecast based operations called Forecast Coordinated Operations. A detailed discussion is found in Section 6.0 of this report. Two other measures that were deemed too costly to pursue under the YFSFCP were forward to DWR for further consideration. These measures were to re-operate the Thermalito complex and to surcharge Lake Oroville. More information on the YFSFCP is found in Section 7.0 of this report. The Comprehensive Study and the SCFS also generated lists of potential measures, Sections 8.4.2.1 and 9.3 of this report respectively, none of which were specify to the Oroville Facilities.

DWR has determined that the evaluation of flood protection measures is not appropriate under the Relicensing program. This determination is based largely on the fact that the Commission in accordance with federal law has relinquished its authority to prescribe flood protection measures at the Oroville Facilities to USACE. DWR operates the facility in accordance with the guidelines set forth by USACE. Therefore, DWR does not anticipate conducting any additional evaluations as part of the Relicensing process of any of the measures identified. DWR will continue to work with the agencies responsible for flood control in the region outside of the relicensing process.

13.2 STATUS OF MEASURES BEING EVALUATED OUTSIDE OF RELICENSING

13.2.1 Structural Modifications

Structural modifications in the project facilities (Obermeyer Gate - Structural Solution) were abandoned by the YFSFCP. DWR has also chosen not to pursue installing Obermeyer gates, or any other structure requiring human or mechanical operation, on the emergency spillway.

13.2.2 Coordinated Operations for New Bullards Bar and the Oroville Facilities

The Forecast-Coordinated Operations (F-CO) project is an element of the YFSFCP. The purpose of the F-CO project is to improve the real-time flood control operations of the New Bullards Bar and Oroville facilities in order to reduce peak flows on the Feather and Yuba Rivers and downstream, as well as provide regional flood control benefits.

One of the initial tasks of the F-CO project includes assessing the potential for improving operational guidance and operating rules for Lake Oroville and New Bullards Bar Reservoir. DWR, with the support of the U.S. Army Corps of Engineers (USACE), the Yuba County Water Agency (YCWA), the National Weather Service—California-Nevada River Forecast Center (CNRFC), and other entities, hired an outside consultant to assist in the thorough flood operation assessment of the two facilities. The activities include, among others, using the planning mode of the HEC ResSim program to compare the effects of various flood scenarios under different interpretations of the existing reservoir operating rules for Lake Oroville and New Bullards Bar Reservoir with the uncertainties of downstream local flows, travel times, reservoir inflow forecasts. The results will help determine potential improvements to the operational guidance for the Oroville and New Bullards Bar facilities with the concurrence of the USACE.

13.2.3 Re-operation of the Thermalito Afterbay during Flood Events

DWR is investigating the feasibility of utilizing the Thermalito Afterbay during major flood events to provide additional storage capability when it is unable to evacuate water from the main reservoir at the desired rate. DWR staff has investigated this option and has concluded that it may be feasible to implement under some conditions. DWR Operations staff is continuing to assess the ability of the Department to implement this measure. This assessment should be completed by the start of flood control season during 2004.

13.2.4 Improving Communication and Warning System

DWR believes that increased flood warning and emergency preparedness time will be a result of the flood operations assessment that it has undertaken. Additionally, DWR, in coordination with YCWA, implemented a functional FERC-required exercise to test communications during a major flood event. DWR and YCWA operations staff will continue to assess their ability to conduct joint exercises in the future.

13.3 OTHER STUDY RESULTS

Other items not called for as products or deliverables but identified in the study plan's general approach or study plan tasks are summarized below. These include evaluating and, if necessary updating (1) the estimated storm precipitation, (2) the estimated runoff and flood routing, (3) the PMF analysis using soil cover data from Relicensing Study

Plan T4, and consideration of regulatory and/or institutional opportunities to reduce flood hazards including (4) strengthening regulatory control of land use and (5) modification of current notification procedures.

The preliminary PMF report has been distributed to the collaborators and Items 1 and 2 are an integral part of that evaluation. The PMF study uses the latest information available to estimate the storm precipitation and the resulting runoff and flood routing. The PMF study results are summarized in Section 12.0 of this report.

Vegetation mapping conducted as part of Relicensing Study Plan T4 generated more detailed information on soil cover. However, the mapping effort did not extend very far outside of the Oroville Facilities FERC boundary and incorporating this information is unlikely to have a significant effect on the runoff estimations for the PMF study. Therefore, results of the vegetation mapping were not considered in estimating the runoff for the PMF study (Item 3).

Item 4, strengthening regulatory control of land use, is deemed a local government jurisdiction and therefore out of DWR control. No additional activities are planned for this item.

Notification procedures (Item 5) are outlined in the EAP for the Oroville Facilities. The notification procedures in EAP were evaluated and found to meet FERC requirements. DWR conducts yearly exercises to insure that the contact list is current. Updates if deemed necessary are filed with FERC and distributed to EAP binder holders.

14.0 ANALYSES

In an effort to improve readability each section in this report, where appropriate, has its own results and analysis subsections. For detailed analysis of any particular effort go to the appropriate subsection. This section covers only information directly related to the Oroville Facilities Relicensing effort or the Feather River.

14.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

Flood management at the Oroville Facilities is governed by the rules and regulations outline by the Secretary of the Army and is an integral part of the project description for any environmental assessment. The Preliminary Draft Environmental Assessment conducted as part of the relicensing program will need to ensure that we do not encroach on or modify any of the flood control requirements currently in place.

14.2 PROJECT RELATED EFFECTS

The project in this case is obtaining a new license from FERC for the continued operation of Oroville Facilities as a power generating complex. DWR, as part of the relicensing process, has no plans to ask USACE to modify any of the flood control requirements currently in place for the facilities. DWR will also ensure that any modifications to our operations that may result from the relicensing process will not affect the flood control requirements that USACE has prescribed. Therefore, no project related effects to flood management have been identified. However, it is possible to arrive at some preliminary conclusions regarding the proposed flood management efforts currently underway for the Yuba and Feather Rivers.

14.2.1 Feather River Floodplain and Water Surface Profiles

The depicted floodplains are clearly reduced by the presence of the Oroville Facilities. However, this study depicts only the “with Oroville Facilities” condition and does not provide any quantitative comparison to a “without Oroville Facilities” nor to a “with modified Oroville facilities” condition.

14.2.2 Forecast Based Operation of Oroville Dam

FBO may have potential for improvement of American River flood protection, but certain components are needed for its implementation. These are:

- Completion of testing of the stochastic features of the Folsom RRFM, now underway at Utah State University;
- Creation of a planning version of the Folsom RRFM;
- Completion of the HEC analysis of effectiveness and risk of forecast-based advance release. The process was begun with the completion of Phase 1, but the probability

of “false alarm” forecasts must be assessed. Assumption of zero probability for “missed opportunity” forecasts would have little effect on the results;
- Completion of the HRC tools for constructing forecasts on historical hydrology. This will contribute materially to the completion of the HEC work;
- Institutional consensus on probability-based procedures. A concerted education effort will be needed to overcome institutional reluctance to operate under conditions of uncertainty (USACE 2003a).

The potential for FBO in the Yuba-Feather area is less certain. YCWA’s simulations have demonstrated the potential for outlet improvements, surcharge operations, and Thermalito reoperation, but, as reported in Appendix B of the feasibility study report, the effectiveness of FBO is less certain. The fact that DWR and YCWA informally initiated FBO during the 1997 floods also limits the additional flood control benefit to be gained by formalizing the procedure. The greatest benefit of FBO may be in having USACE acknowledge spring refill opportunities. On the other hand, Appendix G of the feasibility study report identifies FCO actions that may have potential for substantial improvement in flood protection (YCWA 2002; YCWA 2003).

Further steps toward FCO implementation would be:
- Completion of operations versions of the Yuba-Feather RRFM, being prepared at Utah State;
- Improvement of telemetered data sources;
- Development of an unsteady flow routing model for the Yuba and Feather Rivers below Oroville and New Bullards Bar;
- Creation of a planning version of the Yuba-Feather RRFM;
- If FBO is to be a part of the FCO, an analysis of its effectiveness and risk both at Lake Oroville and New Bullards Bar Reservoir;
- Completion of the HRC forecast synthesis tools and their application to the Yuba-Feather forecasts;
- Institutional consensus on probability-based procedures. As on the American River, a concerted education effort will be needed to overcome institutional reluctance to operate under conditions of uncertainty;
- An interagency agreement for operating the system toward jointly optimal conditions. This would determine the model operator and the operating decision maker, whether DWR, YCWA, or a joint operating organization;
- Year-round use of the developed procedures;
- Buy-in by USACE and appropriate changes in the water operations manuals for both reservoirs (YCWA 2003).

HEC identifies flood season encroachment into a reservoir’s flood control space upon forecast of good weather as a possible mitigation for water supply and power generation losses due to advance releases. This relaxation of the operating rules would have little benefit when its effects are negated by the ensuing forecast of a storm that would require evacuation of the flood reservation. It would only be effective as the last flood control-related action of the flood season and then only when the season's runoff would not otherwise fill the reservoir. However, the technique deserves further investigation and could provide a technically sound basis for earlier refill, an action that is intuitively low-risk and high-gain (HEC 2002).

14.2.3 Sutter County Feasibility Study

Better flood control facilities on the Feather River below Lake Oroville would reduce the inherent danger of flows at or near the controlling values on the Feather River and Yuba River.

15.0 REFERENCES

Where reference indices in the text appear at the end of a section or paragraph, they may apply to material anywhere in the section or paragraph. Where indices appear at the end of a sentence but inside the paragraph, they apply only to the preceding sentence.

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APPENDICES